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ENVIRONMENTAL MONITORING MANUAL

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WHITE RIVER SHALE PROJECT

ENVIRONMENTAL MONITORING MANUAL

Prepared by

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April 1982

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1.0 INTRODUCTION

The White River Shale Oil Corporation (WRSOC) is planning for the joint development of Federal Prototype Oil Shale Lease Tracts Ua and Ub in Uintah County, Utah (collectively known as the White River Shale Project). This development will be significant in scope, as described in the Detailed Development Plan (DDP) approved on March 2, 1982, and will have the potential to modify, in a substantial manner, the physical and biological environment on and near the tracts. Thus, it is necessary to develop and implement a detailed environmental monitoring program which will track the impacts of project development, evaluate the success of our planned mitigation measures, and provide feedback to design and operations to minimize any identified or irreversible effects.

The basic description of our monitoring program was provided in Section 6 of the DDP. This document expands and further defines WRSOC's long-range field environmental monitoring plans. It is the product of seven years of continuous field monitoring (1974-1981) at the project site, during which time the environment was characterized, coupled with a careful evaluation of the probable impacts expected from our current tract development plan. Figure 1.0-1 is a simplified perturbation/response diagram for the project which identifies those biotic and abiotic parameters likely to be affected by project development.

This environmental monitoring manual, and the program defined by it, is a snapshot of what is in reality a dynamic process. Thus, as our knowledge of the environment grows, our understanding of the effects of development increases (especially our understanding of the pathways along which project impacts will be manifested). Moreover, as the requirements of various environmental laws, regulations, permit conditions, or lease stipulation change, so too will the emphasis and design of this monitoring program change. It is our intent to review the

FIGURE 1.0-1

INTER-RELATIONSHIPS OF PARAMETERS WITH PROJECT ACTIVITIES OR POTENTIAL IMPACTS

CHAPTER NUMBER	2			3									4							5										6			
	AIR QUALITY	VISIBILITY	METEOROLOGICAL FACTORS	ANNUAL PLANT BIOMASS	PERENNIAL PLANT PRODUCTS	LICHEN PRODUCTION	LITTER FALL	PLANT CHEMICAL COMPOSITION	PLANT CONDITION	PLANT UTILIZATION	SOIL PHYS. - CHEM. FACTORS	SOIL MICROBIOLOGY	PERIPHYTON BIOMASS	INVERTEBRATE BIOMASS	DRIFT	PERIPHYTON PRODUCTION	INVERTEBRATE PRODUCTION	DECOMPOSITION RATE	PHYSICAL FACTORS	RESIDENT BIRDS (1)	MIGRATORY BIRDS	SMALL MAMMALS	MEDIUM MAMMALS	REPTILES	FOLIAGE INVERTEBRATES	SOIL INVERTEBRATES	WATERFOWL	RAPTORS	THREAT. & ENDG. SPECIES	LARGE MAMMALS	SURFACE WATER QUALITY	GROUNDWATER QUALITY	FLOW (SURFACE-GROUNDWATER)	SURFACE WATER SEDIMENT LOAD
SURFACE DISTURBANCE	●	●	●	●	●	●	◆			◆	●	●	◆	◆	◆	◆	◆	◆	◆	●	●	●	●	●	●	●	◆	●	◆		●	●	●	●
NOISE/ACTIVITY	●	●				●				◆	◆	◆								●	●	◆	◆	◆			●	●	◆	●			◆	◆
GASEOUS AIR EMISSIONS	●	●	●	●	●	●	●	●	●	◆	●	●	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	●	◆	◆	◆	◆		◆			
DUST	●	●	●	●	●	●	●	●	●	◆	●	●	◆	◆	◆	◆	◆	◆	◆	◆	◆	●	●	●	●	●	◆	◆	◆		●			●
PLANT SITE RUN-OFF											◆	◆	●	●	●	●	●	●	●	◆	◆						◆	◆	●		●	●	●	●
LEACHATE				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	◆	◆	●	●	●	◆	●	●	●	●	●	●	●		
MITIGATION-RECLAMATION	●	◆	◆	●	●	◆	◆	◆	●	●	●	●	◆	◆	◆	◆	◆	●	●	◆	◆	●	●	◆	●	◆	●	●	◆	●	●	●	●	●

1. PRODUCTION AND DISTRIBUTION OF POPULATION

● DIRECT IMPACT ⟶ PROJECT ACTIVITY MAY CAUSE AN IMMEDIATE RESPONSE IN THE MEASURED PARAMETER.

◆ INDIRECT IMPACT ⟶ PROJECT ACTIVITY WHICH, THROUGH AN IMMEDIATE RESPONSE IN ONE PARAMETER MAY CAUSE A DELAYED OR SECONDARY RESPONSE IN A RELATED PARAMETER.

program and its results with the Oil Shale Office on an annual basis at a minimum in order to identify and implement improvements which would make the program more timely and/or more responsible. While changes in the program are inevitable, they will be instituted only in consultation with the Oil Shale Office.

1.1 Purpose of the Monitoring Program

The Oil Shale Office, in "Guidelines for Monitoring the Environmental Effects of Development on the Federal Prototype Lease Tracts" (April 1979), indicated that a primary goal of the Federal Prototype Oil Shale Program is, "To insure the environmental integrity of the affected areas and at the same time develop a full range of environmental safeguards and restoration techiques that will be incorporated into the planning of a mature oil shale industry..." The Oil Shale Lease Environmental Stipulations for Tracts Ua and Ub require the lessee to conduct a monitoring program before, during, and subsequent to development operations. This monitoring manual will describe the procedures involved in implementing such an environmental monitoring program for the White River Shale Project (WRSP).

The major goal of the program is to provide a body of information which describes the ecology of the project area in a manner which will:

- Allow assessment of changes occurring in the physical and biological characteristics of the tracts as a result of the impact of surface disturbances and pollutant discharges.

- Guide analysis of cause and effect thus leading to appropriate mitigation planning.

- Guide and assess the effectiveness of mitigation and reclamation measures.

This goal will be met by accomplishing the following tasks which are detailed in the manual:

- Describe methods which will be used to document the environmental conditions that exist in the project area.

- Identify candidate monitoring parameters, sites, and schedules based on the probability of impact, importance, legal requirements, measurability, interpretability, and cost-effectiveness.

- Develop statistical procedures for detecting and evaluating the degree of impact.

- Develop a quality control/quality assurance program.

- Identify criteria for selection of threshold values for specific parameters.

- Describe the contingency measures to be implemented if the operational monitoring program fails to explain an environmental perturbation.

A substantial effort has been invested in the characterization of baseline conditions for the tract area, especially the identification and quantification of environmental trends. Implementation of the monitoring progam described herein will provide the data and the format with which to assess the degree and significance of the environmental effects of project development.

1.2 Development of the Monitoring Program

The WRSP monitoring program is driven by the need to identify and evaluate the environmental effects of developing the oil shale resource

on Ua and Ub. This involves a full understanding of the physical and chemical processes involved in the mining, processing, and disposal of oil shale and oil shale wastes. However, of equal importance is an understanding of the structure and function of the "ecosystem" into which the WRSP will be fitted. Thus, our monitoring program is being developed with recognition of the dynamic interactions between man and nature and within nature itself.

Ecosystems are extremely complex, consisting of a nearly infinite variety of organisms, associations, and synergistic interactions. Development of any natural resource has the potential to affect each of these, in some quantifiable way, through such activities as:

- Surface disturbance (such as site development, road and corridor construction, processed shale disposal, etc.).
- Increased levels of noise and human activity.
- Emissions of gaseous pollutants and dust from construction and operation.
- Leaching of compounds into surface and subsurface water.
- Habitat enhancement/reclamation

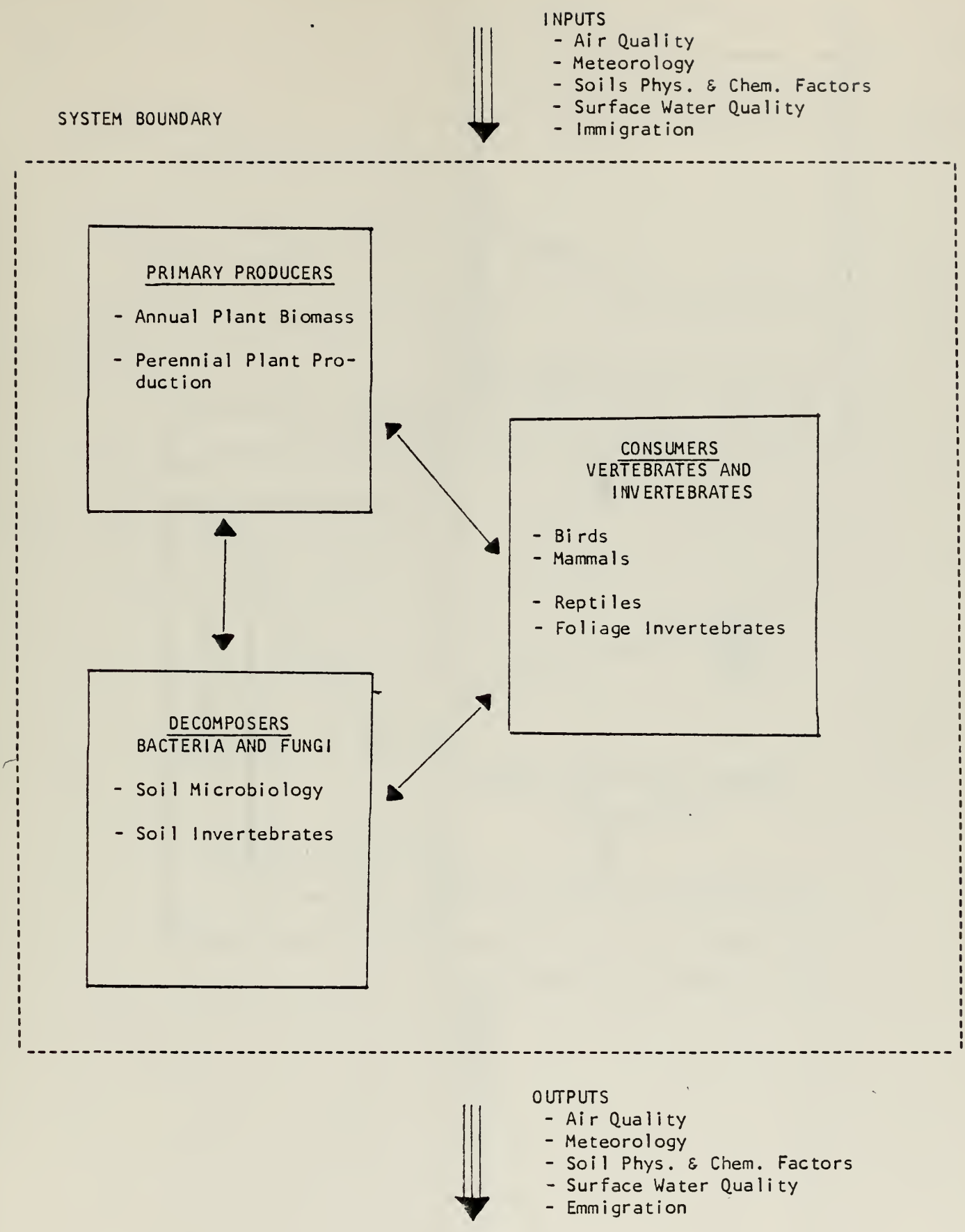
Ecosystem response to these activities may be inhibitory or stimulatory and may or may not be significant over time. To proceed with a logical, effective, and efficient monitoring program, then, requires an understanding of the individual elements of the ecosystem and their interrelationships.

The standard approach to develop a monitoring program has been to use individual structural components (parameters) to assess impacts on biological systems. Parameters that differ in range (variance) or

level (mean or average) from previously-measured values are evaluated to determine if the differences represent statistically significant alterations from normal conditions. Although ecosystem characteristics are inherent in the design of these programs, data analyses have occasionally proceeded without proper consideration of the structural and functional processes. This standard approach only identifies change and does not provide a logical mechanism for identification of probable impact pathways. The WRSP monitoring program by incorporation of ecosystem concepts provides a mechanism which identifies both the dominant parameters and relationships important to pathway analysis.

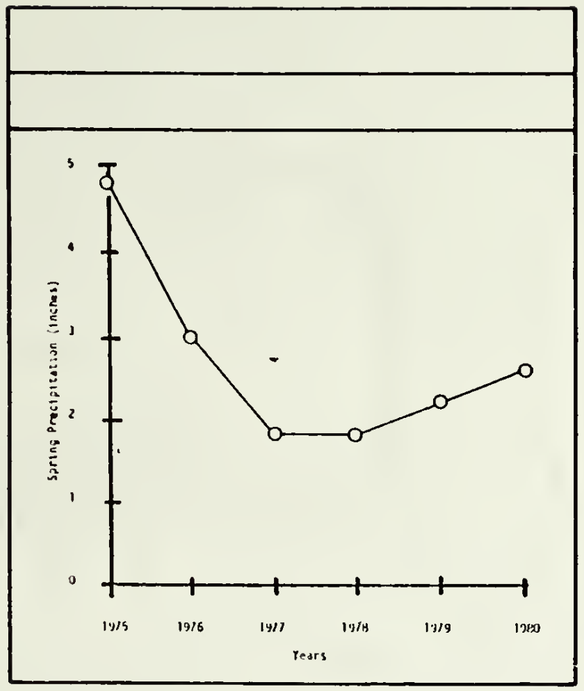
Development of the WRSP monitoring program is progressing through three levels of resolution. First, a generalized concept of an ecosystem affected by both natural inputs (climatic, meteorologic, geologic, and biologic) and anthropogenic inputs (i.e. energy development) is developed. Second, a detailed qualitative description of the cold desert environment of Ua and Ub is developed (see Figure 1.2-1). Finally, the identified structural and functional parameters are then measured and statistical relationships are generated. The statistical relationships provide a method for tracing the pathway of an impact as well as a framework for monitoring effects not only on the levels of parameters but also on relationships between parameters. Figure 1.2-2 shows an example of three of these relationships. The monitoring of relationships as well as parameters makes the program unique, more sensitive, and more effective than conventional monitoring programs.

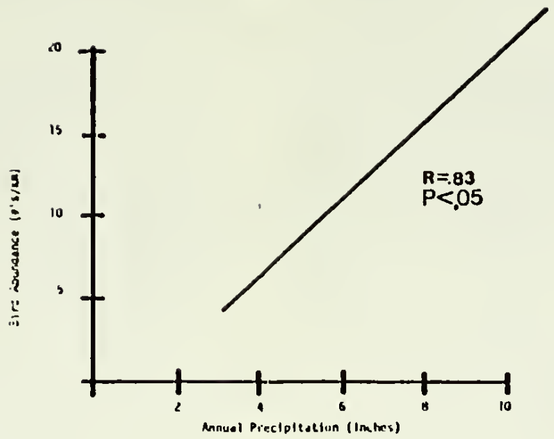
This monitoring manual emphasizes those programs which will be implemented to measure environmental changes occurring as a result of project developent and provide means of determining cause and effect. To support "field" monitoring efforts, extensive "source" monitoring programs will also be developed to aid in determining "cause." The source monitoring programs are not included in this manual, but will be designed and implemented as the project develops.

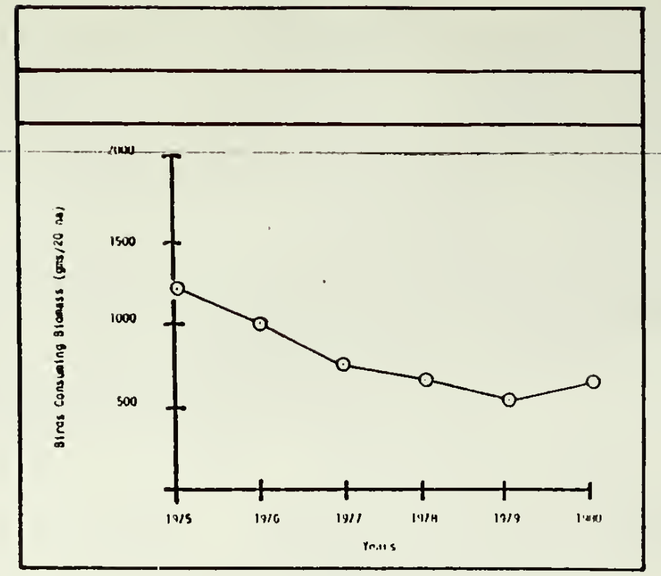


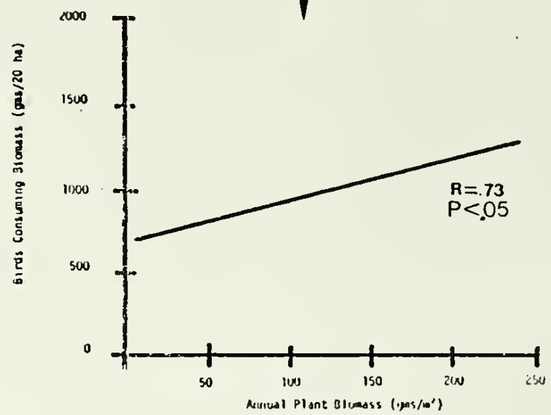
ECOSYSTEM FUNCTION AND INTER-RELATIONSHIPS

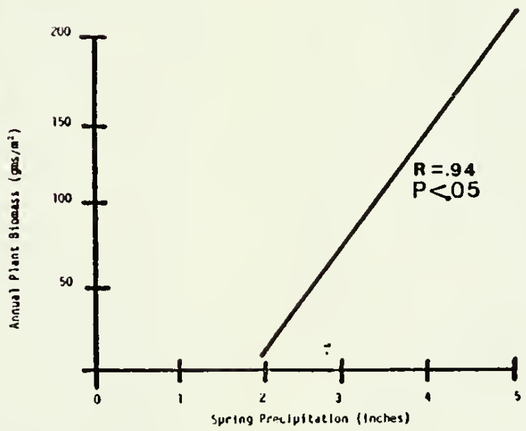
FIGURE 1.2-1

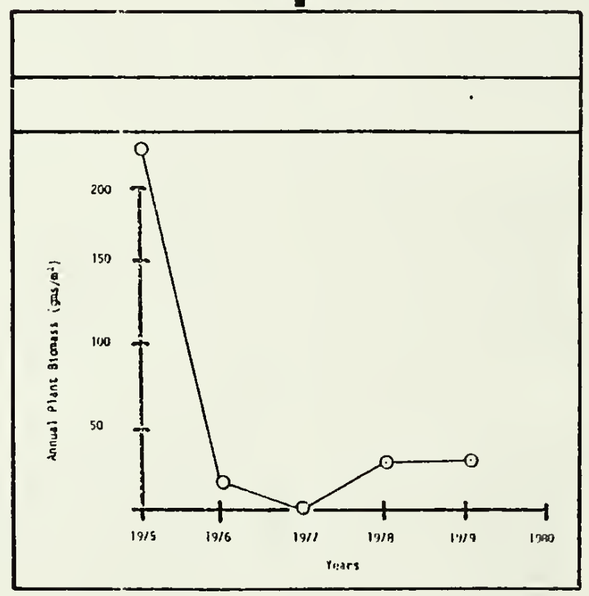












DEVELOPMENT OF STATISTICAL REPRESENTATIONS OF ENVIRONMENTAL RELATIONSHIPS

FIGURE 1.2-2

1.3 Parameter Selection Criteria

The parameters selected within each discipline are subject to expansion or exclusion from the monitoring program as our understanding of the environment increases and the important interrelationships within and among disciplines become more refined. This is true of the sampling site(s) and sampling schedule, as well. Changes in the monitoring program will occur only following review and approval by the OSO.

Each parameter selected for the monitoring program meets the following criteria:

- o Relationship to Impact - Each parameter relates to expected perturbations from oil shale development and the significance of potential impacts.

- o Ecological Importance - Ecological importance involves the degree of interdependence of a parameter with other parameters, its sensitivity to environmental change, and its value as an early indicator of potential impact.

- o Measurable - The ability to measure a particular parameter in a timely manner relies on experience gained during the baseline period and its statistical relevance (i.e. the parameter's usefulness in hypothesis testing).

- o Interpretable/Interrelatable - Each parameter allows for rapid interpretability within each discipline and among the disciplines with regard to determining the cause of a change. Project designs allow for coordination of intra- and inter-disciplinary sampling in location and time so that statistical comparisons may be made. Sampling size (N) for parameters are selected recognizing the inherent variability within parameters so that statistical differences can be detected (see Table 8.4-1).

- o Cost-Effectiveness - This criterion interacts with all other selection criteria in order to guarantee accuracy and precision without being cost prohibitive.

- o Recreational, Economic, Political and Legal Importance - This criterion relates to parameters with high aesthetic value, public attitudes, and local, state and federal requirements.

In some instances, a parameter, while meeting some of the selection criteria, has not been included in the operational monitoring programs. Some parameters may be needed only occasionally due to special circumstances, while others are accepted as being integral to effective monitoring. Thus, parameters were selected in a three-tiered approach to monitoring:

- o Operational Parameters - Essential to the monitoring effort because they meet all of the selection criteria.

- o Potential Parameters - Appear promising or useful as environmental indicators but require further evaluation and verification before inclusion as an operational parameter. These parameters will be evaluated and included or discarded as further study dictates.

- o Contingency Parameters - Used in special conditions or in contingency sampling where increased or specialized sampling is required when the operational program is unable to confirm or deny the cause (pathway) of a significant change in the environment.

This approach allows parameters to move from category to category in the following manner. A potential parameter (community level or other) which is being tested might prove statistically to be an accurate indicator of one or more operational parameters. This could result in

less time being necessary to detect a change and a lowering of costs. This potential parameter would then be included in the operational category while the operational parameters it replaces would be moved into the contingency category.

1.4 Monitoring Manual Organization

In addition to the introduction, this manual is organized into five chapters describing each major environmental discipline (air, vegetation, aquatic biology, terrestrial fauna, and water resources), another chapter describing a series of special studies planned for WRSP, and a final chapter describing interrelationships within and among disciplines. Each discipline has its own program design and objectives that are compatible with the overall objectives stated in Section 1.0 above. Each chapter also contains a rationale for program design, discussion of methods and quality assurance procedures, a description of data management and analysis procedures, and discussion of contingency procedures.

Program rationale for each discipline stems from the identification of impacts expected to occur from project development. These are more fully discussed in Section 5 of the DDP. Full justification is provided for parameter selection, site selection, and schedule selection.

Sampling and sample analysis methods are also discussed briefly in each chapter. References are provided as to the source of the method, if generally accepted. Since WRSOC is vitally concerned with improving upon established techniques, methods which are newly developed or which are improvements upon existing procedures will be discussed in greater detail. A listing of materials required by the program is also provided in each section.

Quality assurance and quality control procedures are those methods which preserve the integrity and accuracy of data presented in a report

or study. Because of the detail and amount of data involved in this monitoring study, a brief section summarizing quality assurance and quality control procedures is included for each discipline.

Quality control assures that the data that is originally recorded is accurate within the limits of the measuring device (i.e. that instruments are working properly or that observers are recording data correctly). Quality assurance is a system of activities to ensure that adequate checks of the accuracy of the data are made (i.e. that quality control is being conducted correctly, or that data management procedures are being followed). Quality assurance may be viewed as "external quality control" and includes those activities which are performed on an occasional basis (versus the routine checks of quality control), by a person outside of the normal routine operations, e.g. on-site system surveys, independent performance audits, inter-laboratory comparisons and periodic evaluation of internal quality control data.

The sections on data analysis begin with a discussion of data management. Data management is the process of collecting, storing, and retrieving data that is recorded in the field or laboratory. Each particular branch of science has its own procedures because of the techniques and format unique to the discipline, and these procedures will be defined for each discipline. All data collected for the WRSP will be handled in a manner useful to both the Project and the Oil Shale Office. All computer tapes will have the following: 1600 density, nine-track, EBCDIC, block size, logical record length, format and file number.

Each data analysis section also describes the methods which will be used to evaluate field data produced by the monitoring program. Within each discipline there is a listing of the important statistical tools available to interpret the data and examples of how these will be applied. Chapter 8 concludes the discussion of data analysis by describing the interrelationships which exist among the disciplines and

how they may be used in determining the cause of an environmental change.

Contingency planning, as discussed for each discipline, describes a series of logical steps that are taken after a critical or threshold value is reached. The purpose of the contingency plan is to determine whether a critical value was exceeded because of a development-related activity, and if so, design a plan for subsequent action. Most project-related impacts will be conveyed throughout the ecosystem and thus affect parameters within several of the environmental disciplines. Thus, the analysis of interrelationships chapter, both between and within disciplines, is a major part of contingency planning. Using the relationships that are described in Chapter 8, the pathway of an impact can hopefully be followed until its cause is determined.

1.5 Implementation

The monitoring program described herein is already being implemented for WRSP. It is a logical outgrowth of field environmental monitoring that has preceded without interruption since late 1974. It will continue to be implemented through the use of consultants knowledgeable in one or more environmental discipline and under the direction of the WRSOC. Because it is of necessity a dynamic program, changes will be implemented from time to time in consultation with and with the approval of the Deputy Minerals Manager - Oil Shale, Oil Shale Office.

1.6 Acknowledgements

This manual was prepared by those consultants currently involved in implementing the monitoring program. WRSOC wishes to thank each organization, and each individual, involved in its preparation. The organizations involved in preparing this manual include:

AeroVironment, Inc.
Bio-Resources, Inc.
Ecosystem Research Institute
Native Plants, Inc.
Ralph M. Parsons Company
VTN Consolidated, Inc.

1.7 Glossary

This manual will use many words that have definitions that have been unclear through diverse use. The following define potentially confusing terms as they are used in this monitoring manual.

Baseline: The condition of the environment as documented by all data collected prior to significant development activities.

Contingency Plan: A plan or work scope for conditional occurrences; that is, if "A" happens then "B" will be conducted.

Critical or Threshold Value: The criteria used to decide between two different alternatives; i.e. the criteria used to differentiate between natural variation and project-related impact; or between alternative hypotheses. Statistically, this is usually called an "alpha" value.

Impacts: An observed EFFECT that occurs in a parameter, component or interrelationshp that results from a pertubation.

Mitigation: The lessening or amelioration of the effect associated with some impact; "impact reduction."

Monitoring: Measurement of the environment in order to determine impacts or changes.

Parameter: A measured variable which quantifies a component of a system. It is used to reflect changes in the system and describes relationships between components.

Pathway: A means by which changes, impacts, or relationships are transmitted. Also can be used to determine critical areas (i.e. indicator steps) in impact mitigation.

Pertubation: A CHANGE in the state (level, condition) of a parameter; a disturbance that occurs in an environmental system resulting in a change in components or processes of the system.

Surveillance: A continued program of surveys systematically undertaken to provide a series of observations in time.

Survey: An excercise in which a set of standardized observations (or replicate samples) is taken from a station(s) within a short period of time to furnish qualitative or quantitative descriptive data.

2.0 AIR RESOURCES

2.1 Program Design and Rationale

The air quality on Tracts Ua and Ub has been monitored continuously since baseline data collection began in 1974. As data on baseline pollutant levels were obtained and their general lack of spatial variation was demonstrated, the number of monitoring stations was reduced during the second year of the baseline period. The objectives of these baseline measurements were twofold:

- To characterize the air quality environment in the vicinity of the tracts in sufficient detail to provide a complete description of the baseline situation against which future air quality could be compared.

- To describe the meteorological environment in the vicinity of the tracts in sufficient detail to provide input data for modeling to simulate the dispersion of air pollutants that would be generated by future developments on the tracts.

The air resources baseline monitoring program was officially completed on January 15, 1977. During subsequent years (1977 to the present), monitoring of air quality has continued at one site and meteorological measurements have continued at four sites. This additional monitoring, known as the Air Resources Interim Monitoring Program, has provided continuity for the baseline program and helped satisfy a third objective:

- To determine the year-to-year variation in the baseline air quality and meteorology of the area, in order to see whether the baseline measurements adequately represented the ambient conditions.

Data collected through 1980 showed that, except for sporadic occurrences of high levels of non-methane hydrocarbons (NMHC), the air on the tracts was generally free of gaseous pollutants. The only other gaseous pollutant present in measurable quantities was ozone (O_3), which has a natural non-zero background level. Otherwise, almost all instruments measuring gaseous pollutants were recording at their lower limit of detection most of the time.

The types of instruments available for routine and continuous monitoring of NMHC are inadequate for precise and accurate measurements. On January 10, 1978, EPA Region VIII issued a letter discouraging the monitoring of NMHC on oil shale lease tracts. Following EPA's suggestion, and with the approval of the Deputy Minerals Manager - Oil Shale, total hydrocarbons (THC) and methane (CH_4) were monitored until May 1980, but NMHC values were not analyzed. These measurements were discontinued after May 1980.

The highest hourly-averaged ozone concentration was 190 ug/m^3, as compared to the ozone National Ambient Air Quality Standard (NAAQS) of 235 $\mu g/m^3$. The annual average values varied between 61 $\mu g/m^3$ and 73 $\mu g/m^3$. The year-to-year variability of ozone is governed by the movement of fronts over the tracts, which is accompanied by the introduction of stratospheric ozone to the surface (as discussed by Chan and Smith 1981).

The annual geometric mean of particulate concentrations ranged from a high of 24.5 $\mu g/m^3$ in 1975 to a low of 12.5 $\mu g/m^3$ in 1979. These values were lower than the secondary annual geometric mean NAAQS of 60 $\mu g/m^3$. The most stringent short-term TSP standard is the national 24-hour secondary standard of 150 $\mu g/m^3$. The highest 24-hour TSP concentration recorded was 127 $\mu g/m^3$ in 1980.

With the development of the White River Shale Project, ambient levels of particulates and gaseous pollutants will change. Thus, the air resources monitoring program will take on new objectives. These are:

- To quantitatively determine the air quality impacts of various levels of oil shale development and operation on Tracts Ua and Ub;

- To demonstrate that impacts of the air contaminants emitted by the facilities are in compliance with the National Ambient Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act, as well as with Utah air quality standards;

- To identify areas where additional control of air contaminant emissions would be appropriate or necessary;

- To continue observing the long-term evolution of regional air quality;

- To continue monitoring the meteorological environment to provide additional data for future modeling efforts as well as to monitor meteorological events (e.g. frontal passages) that might affect the regional air quality.

To achieve these objectives, the program will be designed with some knowledge of expected impacts from the development of the White River Shale Project. Such impacts have been predicted through diffusion modeling and results presented in the Detailed Development Plan (WRSP 1981). In brief, emissions from the project consist of particulate matter from sources on the surface and of gaseous pollutants from elevated sources. The transport of emissions at the surface could be different from the transport of emissions aloft, depending on the depth of the surface boundary layer. This has been considered in the design of the monitoring program (Section 2.1.3).

Figure 2.1-1 shows a representative isopleth plot of annual average pollutant (NO_2) concentrations, predicted by the modified VALLEY model. Because of the assumptions in the model, the actual locations of maximum concentrations, as well as the magnitude of the maximum concentrations that would be observed, could be quite different from those predicted. Thus, Figure 2.1-1 should be used only as a rough guide on where monitors are to be located. The flow regimes in the area should be considered in deciding on the exact locations of monitors. The influence of two different flow regimes on the ambient levels of pollutant concentrations is quite obvious in the figure, which shows a bimodal distribution with a peak to the northwest of Tract Ua and a peak to the east of Tract Ua. The first peak comes from the transport of pollutants toward the White River by the nighttime drainage winds, while the second peak is attributed to the transport of pollutants by the daytime synoptic flow. Thus, the program should be designed to allow monitoring of pollutants downwind of the sources under these two regimes.

Sound level measurements will also be made as part of the air resources program. Sound level measurements were made in quarterly surveys during the baseline data collection period. The measurements showed, as expected, that the Ua and Ub area sound levels were low (24-26 dB(A) with no wind at sites away from the White River) and uniform from season to season. Noise sources were primarily natural (e.g. insects, running water, rustling grass, wind). Background levels near the White River ranged from approximately 30 dB(A) to 60 dB(A) in moderate wind.

The objectives of the sound level measurement program are:

- To update the baseline sound levels before construction begins.
- To document the sound levels produced by construction and operation.

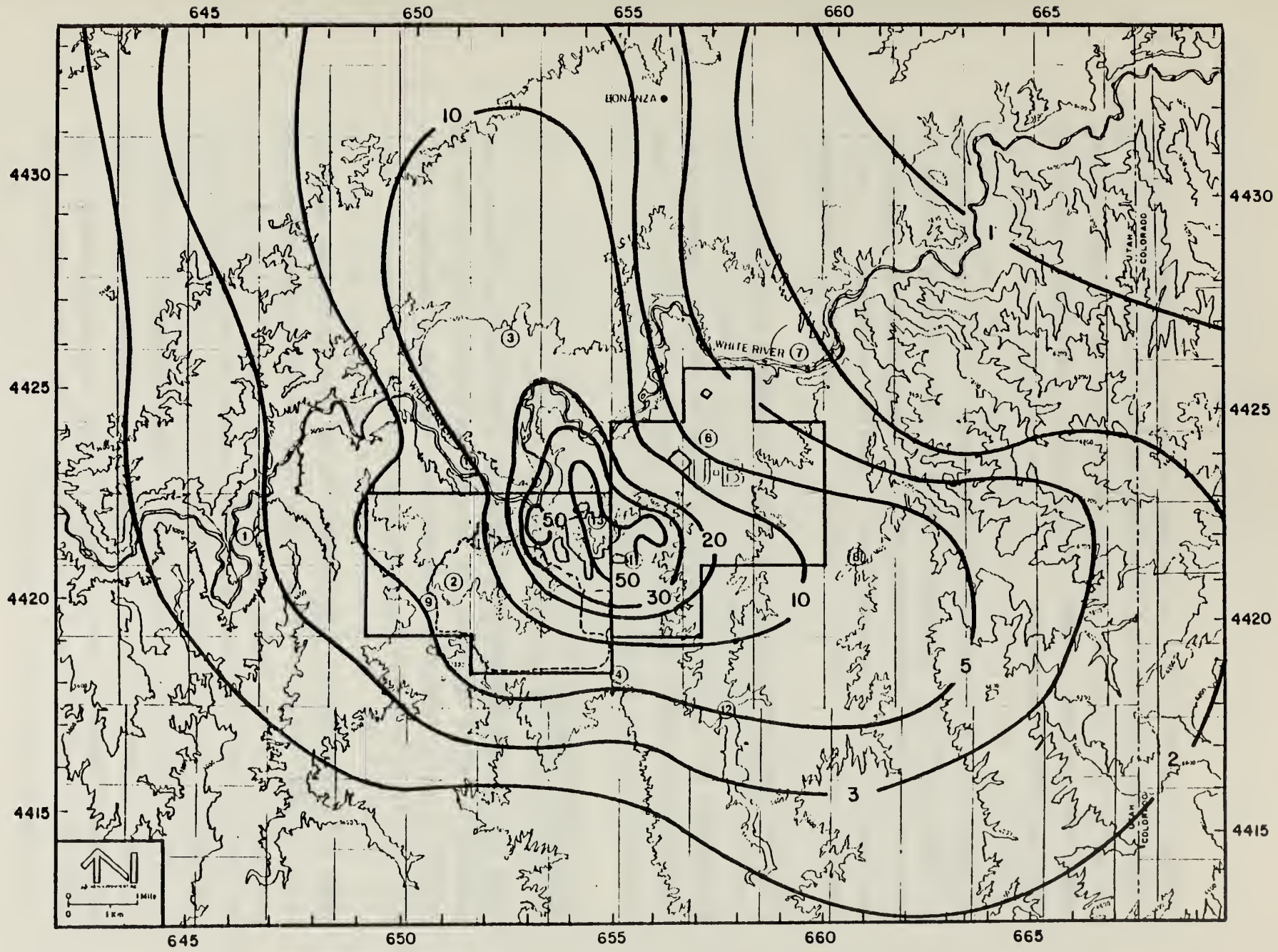


Figure 2.1-1 CONCENTRATION ISOPLETHS OF PHASE III NO_2 ANNUAL AVERAGE INCREMENTS ($\mu g/m^3$) AS PREDICTED BY THE VALLEY MODEL (WRSP DDP)

Ambient sound levels are of interest at locations accessible to the public during construction and operation, and that are likely to be visited by the public for purposes unrelated to the oil shale activities. The ecological effects of noise (for example wildlife populations) are also of interest.

As pointed out in the beginning of this manual, the monitoring program is a dynamic one. Changes will be made as a result of changes in environmental laws, improvements in our understanding of emission on the tracts and the transport and dispersion mechanisms in complex terrain, and the continuing evolution of measurement instruments.

2.1.1 Air and Noise Monitoring Program: Parameters to be Measured

The ambient air monitoring program will consist of two types of parameters. Operational monitoring will consist of Groups I-III and Contingency monitoring will include Group IV parameters.

Operational Parameters

Group I: Long-Term Air Quality Evolution. These are continuous measurements at fixed locations, at or near the sites of baseline-period stations whenever possible, recording the continuing long-term evolution of background and regional air quality.

Group II: Direct Impact of Emissions. These are continuous measurements, either on or off tract, that are expected to document the greatest air quality impacts of a particular aspect of the facility. (This group also includes meteorological measurements to help in determining plume transport.) Monitoring sites will be selected initially on the basis of experienced judgment supported by rational dispersion modeling. Sites may be moved as field surveys identify more appropriate locations and as new facilities are constructed. The number of sites will increase as the scale of the mining and retorting activities increases and as the need arises.

Group III: Area Impact. These are continuous measurements, generally off tract, where the air pollution impact of the facilities could be noticeable (though at levels that are well below all standards or regulations); where the receptor could be sensitive (e.g., a residential community); or where the effect of an adjacent development on the quality of the airflow approaching the tracts could be significant. Such monitoring in the early phases of development would provide guidance for estimating the potential impacts of the later, larger-scale phases, and could serve as an input to their design.

Contingency Parameters

Group IV: Short-Term Intensive Studies. These are short-term detailed measurements to quantify the actual impact pattern of specific sources, to verify the adequacy of the model-based selections for the monitoring stations, and to provide data for increasingly improved simulation modeling.

Table 2.1-1 summarizes the proposed monitoring program and Figure 2.1-2 shows the probable locations of the monitoring sites whose general positions can be predicted at this time. The specific location of Site A15 for regional visibility has not yet been selected. Note that several stations serve more than one function, depending on meteorology. For example, site A10 is downwind of the process area during drainage flow and upwind during synoptic and transition flows. The final locations will be determined after consultation with OSO, EPA, the Utah Bureau of Air Quality, and BLM (as appropriate).

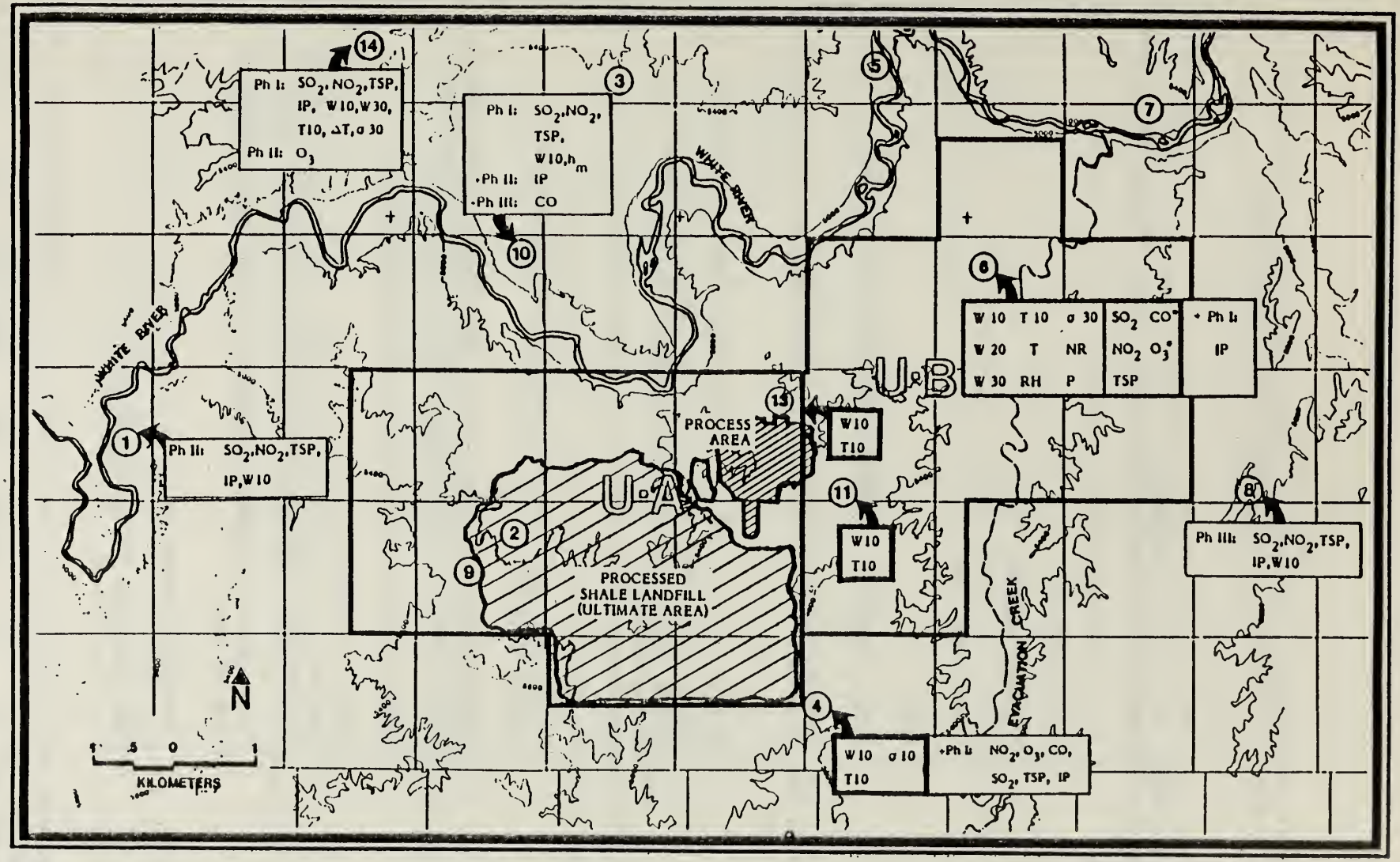
Table 2.1-2 lists the parameters that will be measured on or near the tracts. All the air quality and visibility parameters listed are chosen for monitoring because they are either directly emitted or indirectly affected by the proposed project. Measurement of some of these parameters is also specified in the lease stipulations, as well as being required by state and federal regulatory agencies. Monitoring

Table 2.1-1

SUMMARY OF UA/UB CONTINUOUS AIR QUALITY AND METEOROLOGICAL MONITORING

Site Number	Measurement Group	Measurement	Beginning of Operation
A1	III	Regional air quality impact in drainage flows	Phase II
A4	II	On-tract meteorology	Currently operational
	I	Background air quality	Phase I construction
	II	Air quality impact south of plant and near processed shale pile	Phase II
A6	I	Background air quality	Currently operational[(a)]
	II	On-tract meteorology	Currently operational
	II	Plant impact during some transition flows	Phase I operation
A8	III	Regional air quality impact	Phase III
A10 (relocated)	II	Air quality impact in drainage flows	Phase I construction
A11	II	On-tract meteorology	Currently operational
A13 (relocated)	II	Plant area meteorology	Currently operational
A14 (new)	I	Background air quality	Phase I operations
	II	Elevated plume impact during transitional meteorology	Phase I operations
A15 (new; site to be selected)	I	Regional visibility	Phase I operations

(a) Measurement role terminates upon commencement of Phase I construction



MEASUREMENTS INCLUDED IN CURRENT PROGRAM

MEASUREMENTS TO BE ADDED TO PROGRAM

MONITORING LOCATION (Sites 10 and 13 are at new site locations; Site 14 is a new site.)

Note: Sites 2, 3, 5, 7 and 9 were operated only during the baseline program
*CO and O_3 measurements at Site A6 will be terminated when Phase I construction begins; all Site A6 pollutant measurements will be suspended temporarily during access road construction nearby.

FIGURE 2.1-2. CONTINUOUS AIR QUALITY AND METEOROLOGICAL MEASUREMENT SITES ON TRACTS Ua AND Ub.

Table 2.1-2

PARAMETERS MEASURED IN AIR QUALITY MONITORING PROGRAM

Type of Monitoring	Parameter
Air Quality[a]	
SO_2	Sulfur dioxide
NO_2	nitrogen dioxide
CO	Carbon monoxide
O_3	Ozone
TSP	Total suspended particulate matter
IP	Inhalable particulate matter ($d < 10\ \mu$)
Visibility	
C_r	Target/sky contrast ratio (measured photographically)
b_s	Light scattering coefficient (measured by integrating nephelometer)
Meteorology	
W10	Wind speed and direction measured at 10 meters above ground level[b]
σ10	Standard deviation of vertical wind speed and horizontal wind direction measured at 10 meters above ground level[b]
h_m	Mixing height (measured by acoustic sounder)
RH	Relative humidity
T10	Temperature, measured at 10 meters above ground level[b]
ΔT	Temperature difference between 10 and 30 meters above ground level
P	Barometric pressure
NR	Net radiation (solar and thermal)

(a) Due to the lack of suitable monitoring techniques, non-methane hydrocarbon measurements will not be made.

(b) Sites A6 and A14 also include wind, temperature, and turbulence measurements at 20 and/or 30 meters above the ground

meteorology is essential in order to understand cause-effect relationships and to provide data for future modeling.

The abbreviations used in Table 2.1-2 are also used in Figure 2.1-2 and in other tables. Table 2.1-3 lists the monitoring program data by site and Table 2.1-4 lists the data by development phase.

Sections 2.1.2 through 2.1.5 describe each measurement group, the rationale for site selection, and the basis for selecting the parameters to be measured.

2.1.2 Noise Level Measurement Program

The noise level measurement program will consist of two types of activities:

(1) Weekly measurement of noise levels at several locations in the project area which characterize the sounds made by natural or human activities; where the public is likely to visit, and at one or more locations that are well removed from human activities.

(2) Measurements of noise levels in conjunction with periodic transects of the tracts as part of the biological measurements program.

During construction, weekly measurements will be made only during daytime. During the subsequent operational period, a parallel set of measurements will also be made at night.

The locations of the weekly noise level measurements are shown in Figure 2.1-3. The location of each site, and its purpose is as follows.

Table 2.1-3

AIR QUALITY MONITORING PROGRAM ON TRACTS Ua/Ub BY PARAMETER[a, b]

Site No.	Air Quality						Visibility		Meteorology							
	SO_2	NO_2	CO	O_3	TSP	IP	b_s	C_r	W	σ	T	h_m	RH	ΔT	P	NR
Group I																
A4[c]	Ia	Ia	Ia	Ia	Ia	Ia			0	0	0					
A14[c]	Ib	Ib		III	Ib	Ib			Ib	Ib	Ib			Ib		
A15							Ib	Ib								
Group II																
A6[d]	0	0	0[e]	0[e]	0	Ib			0	0	0		0	0	0	0
A10	Ib	Ib	III		Ia	II			Ia			Ib				
A11									0		0					
A13									0		0					
Group III																
A1	II	II			II	II			II							
A8	III	III			III	III			III							

(a) Sites are listed by measurement groups, depending on their primary function after Phase I construction begins.
(b) Numerals indicate the project phases in which measurements begin; a zero indicates current measurements. Ia implies Phase I construction and Ib implies Phase I operation.
(c) Sites A4 and A14 also serve as Group II impact monitoring stations under specific meteorological conditions.
(d) Site A6 is a Group I station until Phase I construction begins, and will temporarily cease air quality monitoring during construction of the access road nearby.
(e) These measurements will be terminated when Phase I construction begins.

Table 2.1-4

AIR QUALITY MONITORING PROGRAM ON TRACTS Ua AND Ub BY DEVELOPMENT PHASE

Site Number	Present (1981)	Phase I Construction	Phase I Operation	Phase II	Phase III
Group I (Background)					
A4[a]	W10, σ10,T10	Add SO_2,NO_2,CO, O_3,TSP,IP	Continue	Continue	Continue
A14[a]	--	--	SO_2,NO_2,TSP, IP,W10,W30,T10, ΔT, σ30	Continue	Add O_3
A15	--	--	C_r,b_s,TSP,IP, W10[c]	Continue	Continue
Group II (Impact)					
A6	SO_2,NO_2,CO, O_3,TSP,W10, W20,W30,T10, ΔT, RH, σ30,P,NR	Reduce to W10,W20, W30,T10, ΔT,RH, σ30,P,NR	Add SO_2,NO_2,TSP, and IP	Continue	Continue[b]
A10	--	TSP,W10	h_m,SO_2,NO_2	Add IP	Add CO
A11	W10,T10	Continue	Continue	Continue	Continue
A13	W10,T10	Continue	Continue	Continue	Continue

Table 2.1-4 (continued)

Site Number	Present (1981)	Phase I Construction	Phase I Operation	Phase II	Phase III
Group III (Area impact)					
A1	--	--	--	SO_2,NO_2, TSP,IP,W10	Continue
A8	--	--	--	--	SO_2,NO_2, TSP,IP,W10

(a) Sites A4 and A14 also serve as Class II impact monitoring stations under specific meteorological conditions.
(b) Site A6 remains operational for one year after abandonment and reclamation; CO and O_3 measurements will be added for this period.
(c) TSP, IP, and W10 measurements will not be needed at Site A15 if such data is available from another nearby site.

S-3
1.3 MILES FROM BONANZA &
0.3 MILES ALONG HWY. 45
FROM THIS POINT

A14

S-4

A10
S-2

S-5
A6

A13

A11

S-1

A4
S-6

LEGEND

- AIR MONITORING STATION
- NOISE MONITORING STATION

N

AIR QUALITY AND NOISE MONITORING STATIONS

FIGURE 2.1-3

- Site S1, located in Asphalt Wash about three miles from the plant site and separated by a high ridge, will provide measurements of background noise levels on the tracts.

- Site S2, located near the site A10 (but far enough away so that any noise emitted from A10 is not recorded), will provide measurements representative of the area along the White River (and future lake). It will record far-field noise from the plant once construction begins.

- Site S3, along the shoulder of Highway 45 about 1.3 miles south of Bonanza (downgradient and out of sight of the gilsonite plant) will reflect the far-field effects of activities in Bonanza.

- Site S4, at the Ignatio Stage Stop, is an area of public interest. Two measurements will be made here each week in the preconstruction period, one in the morning and one in the evening. These measurements will determine the contribution of the public to noise levels and provide a baseline for the assessment of future oil shale operations impacts. This site will be moved with the historic structures if relocation is necessary because of flooding from the White River Dam.

- Site S5 is situated over a hill from the A6 trailer (north of the A6 tower). This location will provide continuing long-term reference measurements and will quantify sound levels near the construction camp area.

- Site S6 is near the A4 trailer, but sufficiently removed to avoid the noise made by equipment in the trailer. It will serve as a background site before construction, and subsequently will quantify far-field plant noise.

- o Site S7 will be at the visibility monitoring site (A15) and will serve as another background measurement station.

2.1.3 Group I Measurements: Long-Term Air Quality Evolution

The long-term evolution of air quality, referenced against the baseline and pre-construction measurements, is influenced by:

- o Factors external to Ua and Ub development (such as population growth and other energy resource developments), and

- o Factors resulting directly or indirectly from oil shale development on Tracts Ua and Ub.

The goal of Group I measurements is to document this background evolution. Sites A4, A14, and A15 will serve this purpose.

This goal cannot be achieved by measurements from any one site in the area, because all measurement locations can be expected to be affected at one time or another, at least to a small degree, by operations on the tracts. Consequently, the approach will involve two monitoring sites -- Site A4 and Site A14. One of the sites will be generally upwind of the tracts and the measurements there will reflect the quality of air approaching the plant before the plant has any effect on the air.

The data base that describes long-term evolution of air quality in the area will be constructed by combining the measurement data from Sites A4 and A14, using the wind direction data to define which site is more representative of the incoming air quality. To enable these data sets to be compared, both sites will be equipped in a similar manner (for all but a few parameters), the air quality instruments at both sites will be identical (same manufacturer and model), and particular attention will be paid to assure comparable operation.

When Sites A4 and A14 are not serving as background monitoring stations, they will serve as impact monitoring stations. This role, which is especially important for Site A14, is discussed in Section 2.1.4.

Sites A4 and A14 have been situated to define the background air quality, which can be considered to be the general ambient air quality of the region. Several major air pollution sources, other than the Ua and Ub developments, are also being planned for the region. Sites A4 and A14 are not necessarily designed to monitor the specific effects of these off-tract sources on the air quality on the tracts. It is assumed that the impacts of these other sources will be monitored by stations established by those sources specifically for that purpose, and that such monitoring will suffice to describe the impacts of these sources on the air quality of the tracts. If this is not the case, the White River Shale Project may perform such measurements of incoming plumes, as discussed in Section 2.1.5.

In addition to the parameters to be measured at Sites A4 and A14, visibility parameters will be measured at Site A15. This site will be at a new location, since Sites A9 and A2, the locations for baseline visibility measurements, may be affected by dust emissions from the processed shale disposal area. Thus, these sites will not be representative for regional-scale visibility characterization. However, A9 and A2 visibility measurements during 1975 and 1976 were sufficient to characterize the visibility of the oil shale region. For this reason A15 will not commence operation until just prior to Phase I operation.

This monitoring will continue the visibility measurements portion of the baseline data collection period, satisfying an objective of the Prototype Oil Shale Leasing Program pertaining to recording the long-term regional impacts of oil shale development. It is also intended to provide data needed to satisfy the PSD requirements in Section 165 of the Clean Air Act, which requires visibility analyses and air quality monitoring for new sources that could potentially impact any Class I

PSD area. Since other energy developments are also proposed for this area, a cooperative visibility monitoring program to satisfy the needs of several developments would be appropriate. If this is acceptable to all parties, then Site A15 would be located to best record the regional-scale visibility and plume effects of all proposed developments, including the White River Shale Project.

Site A6 is historically the "anchor" baseline air quality monitoring station for the tracts. It thus would have been ideal to keep this site to monitor the long-term evolution of air quality. However, the access road to the project facilities will be constructed adjacent to this site. The air quality monitored at this site during and after construction would no longer represent background. Consequently, air quality monitoring will be temporarily suspended at this site when construction begins and Site A4 will be activated to take its place. Since construction and traffic emissions will not affect meteorology, meteorological measurements will be continued at Site A6. After the road construction is complete, measurements of SO_2, NO_2, TSP, and IP will be made at Site A6, in its new role as a Group II station. Measurements of CO and O_3 will not be continued because plant operation will minimally effect levels of these two pollutants.

A4 is an appropriate site to replace the background functions of A6 since during the two-year baseline program it was demonstrated that air quality was uniform across the tracts. This conclusion was based upon air quality measurements at eight monitoring stations on and near to the tracts (including A4 and A6). Thus, duplicate sampling at A4 and A6 prior to construction is not necessary.

In order to provide a final data set on the environmental conditions of the area, Site A6, with CO and O_3 monitoring restored, will remain in operation for one year after the plant has been decommissioned and reclamation efforts have been completed. Since Site A6 was the key monitoring station during the baseline and interim monitoring periods, the final data can be directly compared to pre-development data.

2.1.4 Group II Measurements: Direct Impact of Ua/Ub Emissions

Both construction and operation phases of the project can be expected to directly affect air quality at some locations in the immediate area. The greatest impact will be felt where the receptor is within a surface-based plume or where an elevated plume touches the ground.

The air quality analyses presented in the DDP predict that the greatest off-tract impacts by surface emissions of particulate matter, SO_2 and by vehicle emissions of NO_2 and CO will occur to the north and northwest of the process area whenever the air drains downhill toward the White River. As shown in Table 2.1-4, some of these parameters will be monitored during Phase I while other parameters will be added as the emissions increase in later phases. Since it is not expected that surface emissions of CO will produce significant air quality impacts during Phases I and II, CO will be monitored at only A4 during these phases. In Phase III, CO monitoring will be added at A10.

The location used for Site A10 during baseline collection will be submerged when the reservoir on the White River is completed. Consequently, Site A10 has been relocated above the reservoir's predicted high water level for the operational monitoring period.

Site A6 will be downwind of the plant during the normal westerly daytime airflow, during which it should record the well-mixed plume of most plant emissions. Since the major emissions of concern are SO_2, NO/NO_x, and TSP, these pollutants will be monitored at this site. Inhalable particulates (IP) will also be monitored at the beginning of Phase I operation. This parameter will be especially useful for determining the plant's impacts on the on-tract campsite, which will be in the vicinity of Site A6.

The anemometers currently operating at Sites A11 and A13 are also in the category of impact monitoring stations, since their measurements

will help in analyzing the direction of plume transport. Because the present location of Site A13 is within the proposed process area, the meterological tower will be moved a short distance prior to Phase I construction.

Because the mixing height and inversion height play such significant roles in determining pollutant dispersion patterns in stable conditions, an acoustic sounder will be installed at Site A10 (rather than at the A6 location of the baseline program) so that the atmospheric layering and drainage flow from the plant site down to the White River can be observed. Such measurements will help in understanding and modeling air pollution impacts of future development.

Elevated plume transport in stable conditions, just below or within an inversion aloft, is likely to be the main mode of transport of the Ua/Ub emissions over distances of more than a few miles. One scenario likely to cause the highest off-tract concentrations of pollutants from elevated stacks involves early morning travel within a stable layer (hence with minimal diffusion) until the stable layer is eroded by thermal mixing from below. This thermal mixing, which usually occurs by mid-morning, can mix the plume to the ground quite rapidly, resulting in a short period of "fumigation" (generally less than one hour duration) with relatively high concentrations. Studies at other energy developments have shown this type of behavior to be common.

Such fumigation accompanies the change in surface airflow from a drainage condition to a transitional condition. The mesoscale drainage flow (which governs plume travel aloft) is from the southeast, and Site A14 is in a location where fumigation could be observed, on a plateau some fives miles to the northwest of the plant site. The sensors on the 30-meter tower there, with their indications of near-surface stability and turbulence, will help quantify the meteorological conditions related to fumigation, if it is observed. Because of this capability Site A14 may also serve as a Group II site.

Site A4 also has a Group II role during Phases II and III of the development when Southam Canyon eventually is filled with processed shale.

2.1.5 Group III Measurements: Area Impact

As pollutants are transported away from Tracts Ua and Ub, they will become mixed by the turbulent air flowing over this topographically complex area; therefore, their concentrations will be relatively low over a relatively large area. Ultimately, the source of these added pollutants will no longer be identifiable and they will become part of the background air quality of the area.

To assist in the quantitative assessment of regional-scale identifiable impacts of the Ua/Ub development, two monitoring stations will be located about four miles east and west of the plant site. The western location, at Site A1 along the White River, will allow monitoring of the quality of the air leaving the tracts during drainage flows. The eastern location, Site A8, will provide data on the quality of the air leaving the project area during normal daytime airflow. These two sets of measurements, combined with some impact measurements at Sites A4, A6, and A14 will provide the data base to definitively characterize the regional-scale impacts of the project. Because plant impacts during Phase I are unlikely to be significant at these sites, Site A1 will not operate until Phase II; Site A8 which will observe the even smaller daytime impacts, will not be commissioned until Phase III.

The regional scale assessments require information on the quality of the air coming into the tracts, both background air and plumes from nearby sources. The background monitoring function is covered by Sites A4 and A14. Daytime (westerly) flows containing emissions from the proposed TOSCO Sand Wash oil shale development 12 miles to the west and Magic Circle would be monitored by Sites A1 and A14. Nocturnal drainage flows from the proposed Paraho development six miles to the northeast would probably flow down from the White River. The monitoring

plan here does not include any provisions for measuring pollutants specifically in the Paraho plume, since that is likely to be a responsibility of the Paraho development. The plume from a third facility, the Bonanza Power Plant Project (Deseret G and T) located 15 miles north of the tracts, is unlikely to significantly affect the annual air quality of the tracts because persistent northerly winds are quite rare; Site A14 is best suited to observe any such impacts if they occur.

2.1.6 Group IV Measurements: Short-Term Intensive Studies

The phased development of Tracts Ua and Ub is highly advantageous in a monitoring program designed to analyze the air quality impacts of the project. Actual impacts of the first phase can be studied to provide information for the environmentally effective design of the next phase, and to more effectively assess future air quality impacts.

The same procedure would be followed after the Phase II operations begin. Air quality data would be collected by the monitoring network for at least one year, and the data would be analyzed to determine conditions under which air quality impacts are significant, and the locations of these impacts. It is possible that the data will suggest that peak impacts will occur at other than the station locations. Consideration will then be given to relocating stations or adjusting the number of monitoring stations, with OSO approval.

To better define the precise locations and magnitudes of peak impacts, special short-term field studies might be performed. Such studies could include more intensive monitoring of plant impacts using additional monitoring equipment or mobile monitors. In some cases, tracer gases or particulate matter tracers might be used to allow better definition of the impacts of specific actual sources, or of sources that are proposed for the next phase. These studies would take place for a few weeks during those times of the year the monitoring data show to be of most concern.

The information from these studies would:

- o Indicate whether some monitoring stations should be relocated.

- o Allow the impacts of plant operations to be evaluated and the procedures for predicting these impacts to be refined. As a result, the design of some plant components proposed for subsequent phases might be changed, or the simulation modeling techniques used to predict impacts might be refined.

- o Provide a data base to more realistically model the impacts of the next phase of development. These data could also provide information for improved definition of the actual consumption of PSD increments as well as for more precise analysis of plant impacts.

If other regulated pollutants are emitted by the process in significant quantities, studies could also include measurements of such pollutants to quantify their concentrations in the ambient air. Pollutants that might be of interest in such studies include non-methane hydrocarbons, sulfuric acid mist, and polycyclic organic matter (if these emissions become the subject of regulations).

2.1.7 Fulfillment of Objectives

To reiterate, the objectives of the monitoring program are:

1. To quantitatively determine the air quality impacts of various scales of oil shale development and operation on Tracts Ua and Ub;

2. To demonstrate that impacts of the air contaminants emitted by the facilities are in compliance with the National Ambient

Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act, as well as with Utah air quality standards;

3. To identify areas where additional control of air contaminant emissions would be appropriate or necessary;

4. To continue observing the long-term evolution of regional air quality, including visibility;

5. To continue monitoring the meteorological environment to provide additional data for future modeling efforts as well as to monitor meteorologic events that might affect the regional air quality.

6. To identify changes in ambient noise levels.

Objective 1 will be achieved by activating Group II and Group III measurements at various phases of the development. By processing the air quality data collected at these sites to give pollutant concentrations averaged over time periods for which standards have been promulgated, it will be possible to determine whether or not the impacts from the development are in compliance with standards, thus satisfying objective 2. Objective 3 will be satisfied by careful analysis of the cause-effect relationships, by identifying the source of pollutants measured at the receptor whenever such concentrations approach applicable standards. Group I measurements are designed to achieve Objective 4. Objective 5 will be achieved by meteorological measurements at all the monitoring sites. Objective 6 will be satisfied by weekly measurements of sound levels at the noise monitoring locations.

2.2 Measurement Methods

Table 2.2-1 lists the measurement methods to be used and the frequency of assessments for each of the parameters to be monitored. Details of the measurement methods for such parameters are discussed below.

Table 2.2-1

AIR QUALITY MEASUREMENT METHODS AND FREQUENCY

Parameter	Measurement Method	Equipment	U.S. EPA-EMSL Reference or Equivalent Designation Number	Measurement Frequency
Air Quality				
SO_2	Pulsed fluorescence	Thermo Electron Model 43	EQSA-0276-009	Continuous
NO_2	Chemiluminescence	Monitor Labs Model 8440E	RFNA-0677-021	Continuous
CO	Non-dispersive infrared absorption	Monitor Labs Model 8310	RFCA-0979-041	Continuous
O_3	Chemiluminescence	Monitor Labs Model 8410E	RFOA-1176-017	Continuous
TSP	High-volume sampler	Sierra Instruments Ultra Vol 3	Reference method	Every 6 days[a]
IP	Size selective inlet high-volume sampler	Sierra Instruments Model 320[b]	N/A	Every 6 days

(a) After tract development begins, daily TSP will be collected.
(b) EPA-proposed changes in the definition of IP may change this selection.

2.2.1 Air Quality

Of the air quality parameters listed in Table 2.2-1, national ambient air quality standards (NAAQS) have been established for SO_2, NO_2, CO, O_3, and TSP. H_2S was monitored during the baseline data collection period, but it is not proposed for continued monitoring due to the insignificant quantities expected. Inhalable particulate matter (IP) is likely to be regulated by a NAAQS in the future; the proposed monitoring program allows for this eventuality.

Although NAAQS exists for non-methane hydrocarbons (NMHC) and lead, the standards are not relevant for this geographic area or for the oil shale process. Consequently, no monitoring of either of these pollutants is proposed. The Oil Shale Office has recognized that NMHC measurements are not a necessary element of an air quality program for such developments, and has relieved all prototype lease operators from the requirement for further NHMC monitoring.

Other pollutants regulated by the Clean Air Act, but not under NAAQS, will be included into the total air monitoring program if there is evidence that emissions of such pollutants might occur at levels that would exceed the monitoring exemption provisions of the PSD guidelines (40 CFR 41.23(i)). Continuous monitoring of such pollutants is unlikely to be needed in any case, but short-term field surveys of specific pollutants might be included in Contingency monitoring. Pollutants in this category include total reduced sulfur (including H_2S) and H_2SO_4 mist. Polycyclic organic matter (POM), which is of interest because of its potential carcinogenicity, might also be included if proposed emission standards (NESHAP) for POM are implemented. The remaining regulated pollutants, such as asbestos, beryllium, mercury, fluorides, vinyl chloride, benzene, and arsenic are unlikely to be of concern.

The baseline data showed that ambient radioactivity in the air, particulate matter, soil, water, and plants was well within normal levels. Radioactivity analyses of drill core samples from the mining zone also showed normal levels of radioactivity. Consequently, no radioactive impacts of the development are expected and no radioactivity monitoring is proposed. Similarly, no significant inorganic carcinogen emissions from the process have been identified and, therefore, no monitoring of such materials is proposed. In both cases, there is no regulatory requirement for such monitoring.

All of the air quality measurements will be performed in conformance with the EPA "Ambient Monitoring Guidelines for the Prevention of Significant Deterioration (PSD)." The monitoring of NAAQS pollutants will be performed using EPA-designated "reference" or "equivalent" methods, in conformity with the provisions of 40 CFR 253.

2.2.2 Visibility

To describe the visibility of the region, the visibility measurements of the baseline data collection program will be resumed with quantitative measurement of vista/sky contrast and the light-scattering ability of the ambient aerosol. The technology for visibility measurement is developing rapidly and the measurement techniques to be used will be improvements in the methods used during the baseline program (Table 2.2-2).

The contrast of selected remote targets against the horizon sky, C_r, will be recorded, using a camera with a 10X or stronger telephoto lens. The image will be recorded on black-and-white film through a filter that matches the film spectral response to that of the eye; a standard gray scale will be exposed on the end of each film; and the target/sky contrast will be read with a densitometer. Since the objective of this program is the observation of long-term visibility trends, such measurements will be made on one fixed day of each month, with

Table 2.2-2

VISIBILITY MEASUREMENT METHODS AND FREQUENCY

Parameter	Measurement Method	Equipment	U.S. EPA-EMSL Reference or Equivalent Designation Number	Measurement Frequency
C_r (contrast)	Photography and densitometry	Olympus Model OM-10	N/A	1 day each month
b_s (light scattering)	Integrating nephelometer	Meteorology Research Inc. Model 1597	N/A	Continuous

observations made at three times on that day. Concurrent color photographs of each vista, using more normal lenses, will display the conditions under which the contrast measurements were being made.

Continuous measurements of light scattering coefficient, b_s, will be made at the visibility site to provide a record of the diurnal and daily variation of the optical effects of the atmospheric aerosol, and will allow testing of the representativeness of the days used for the photographic procedure. Concurrent measurements of TSP and IP at the same location, or at a nearby location, will allow deduction of relationships between light scattering and aerosol mass concentration; wind data will indicate the direction of the probable source.

Insofar as is relevant for this study, the procedures used for visibility measurement will follow the EPA document, "Interim Guidance for Visibility Monitoring." The photographic process to be used has been shown by Allard and Tombach (1980) to be equivalent to the telephotometer in the EPA guideline. Because the visibility monitoring will probably be a cooperative effort among several energy developers, the final design of the program will be refined as other developers' plans become formalized.

2.2.3 Meteorology

The meteorological parameters to be monitored during the operational period are primarily those monitored during the baseline data collection period. In most cases, they are being measured to provide continuing information on the motion of the atmosphere, that allows analysis of the behavior of the potential or actual air pollutant emissions from the plant.

The methods for meteorological measurement will also follow EPA "Ambient Monitoring Guidelines for the Prevention of Significant Deterioration" whenever appropriate (see Table 2.2-3 for details of methods used).

Table 2.2-3

METEOROLOGICAL MEASUREMENT METHODS AND FREQUENCY

Parameter	Measurement Method	Equipment	U.S. EPA-EMSL Reference or Equivalent Designation Number	Measurement Frequency
Wind	Cup & vane anemometer	Meteorology Research Inc. Model 1022	N/A	Continuous
σ (turbulence)	Calculation of r.m.s. wind direction and vertical wind speed fluctuations	AV Model 470 Sigma Processor	N/A	Continuous
h_m (mixing height)	Acoustic sounder	AV Model 300A	N/A	Continuous
RH	Hygrometer	WeatherMeasure Inc. Model H321-S	N/A	Continuous
T	Thermistor in aspirated shield	Meteorology Research Inc. Model 840	N/A	Continuous
ΔT	Matched thermistors in aspirated shields	Meteorology Research Inc. Model 840	N/A	Continuous
P	Aneroid barometer	Texas Electronics Model 2012	N/A	Continuous
NR (net radiation)	Fritschen net radiometer	Micromet Fritschen	N/A	Continuous

2.2.4 Sound

Sound level measurements will be made by a Bruel & Kjaer type 2225 integrating sound level meter. When the ambient sound level is relatively constant in time, measurements will be made on the A-weighted scale, slow response setting. The average reading for one minute is determined by eye, ignoring isolated short and unusual noises (i.e. airplanes overhead, isolated animal or bird noises, explosives, passage of an occasional motor vehicle). When the sound level is highly variable, measurement of Leq (the energy level of the sound) over 60 seconds will also be recorded.

The technician making the sound level measurements will also record his impression of the primary source of the average noise (e.g. running water, wind, insects, rustling leaves, machinery). If the peaks in the noise are fairly frequent, he will also record his impression of their source and the peak sound levels associated with them.

2.3 Quality Assurance/Quality Control

A quality assurance manual for WRSP (Aerovironment 1981), including standard operating procedures for quality control purposes, is currently on file with the EPA, UBAQ, and the OSO for the on-going program. This manual will be updated as changes in requirements and monitoring scope are implemented. A summary of the quality assurance and quality control procedures for monitoring is presented below. Quality assurance and quality control of data processing and management are discussed in Section 2.4.

2.3.1 Quality Assurance Program Design

Quality assurance encompasses all aspects of air quality and meteorological monitoring and sampling. Quality assurance starts with the implementation of a project, continues actively throughout the

monitoring and sampling phase, is an essential part of the sample analysis phase, and ends with final data validation and reporting.

The purpose of the Quality Assurance (QA) program is to obtain good quality data which is suitable for its intended use: representative, complete, precise, accurate, and comparable.

With respect to air quality and meteorological monitoring instruments and programs, the EPA three-volume "Quality Assurance Handbook for Air Pollution Measurement Systems" (U.S. EPA 1975 and 1977) describes in detail the quality assurance procedures the U.S. EPA expects to be followed. The EPA document, "Ambient Monitoring Guidelines for Prevention of Significant Deterioration (EPA-450/4-8-012), also discusses the required level of quality assurance. Quality assurance requirements for specific programs are contained in Appendices A and B to 40 CFR 58, as promulgated on May 10, 1979. The QA program implemented for the air resources monitoring program will meet all applicable EPA guidelines and procedures.

As mentioned earlier, a QA plan has already been prepared for the ongoing monitoring program. This plan will be updated to reflect the changes in the scope of monitoring as the project proceeds into each phase. It establishes the QA policy for the program, and defines the level of quality the program is striving to achieve and the mechanisms that will be used to achieve this level of quality. Specifically, it describes the study, including its objectives, design, and methods. The project organization and assigned responsibilities are given. Most important, the QA program is presented. It identifies the key individuals in QA activities and describes in detail all QA components included in the proposed program.

Specific components of the QA program that are addressed in the QA plan include:

- Internal Quality Assurance Checks
  - span and zero checks, precision checks, and calibrations of field and laboratory instruments
  - control samples
  - replicate analyses
  - specifications for calibration standards
  - documentation
  - training of personnel in the proper procedures

- Corrective Action
  - procedures for reporting problems and documenting corrective actions
  - methods for preventing recurrences of similar problems

- Data Validation
  - methods to be used for routine data quality control and validation
  - methods to be used for investigation of problems

- Reporting

- Audits
  - procedures for third party review of monitoring methods and analytical procedures
  - participation in the U.S. EPA National Performance Audit Program

The QA plan includes a sample of each form in the QA program along with its purpose, the schedule for submitting it, and the individuals responsible for completing and routing it. Use of standard forms, designed specifically to meet the needs of the proposed program, facilitates verification that all prescribed procedures are being followed.

A general schedule for each aspect of the QA program is included in the QA plan. The schedule defines the frequency of QA audits and reviews at each step of the program. A checklist form is used by the QA Manager to conform to the schedule in order to track the progress of the work and to verify the performance of quality assurance reviews at the specified frequency.

The QA plan is distributed to each individual responsible for performing any aspect of the monitoring program. Revisions and modifications of the QA plan will be distributed to each individual on the distribution list so that each individual will be fully informed of procedures and schedules to follow throughout the program.

2.3.2 Quality Control Procedures

Standard operating procedures have been established for the on-going monitoring program and are included in the QA Plan. These procedures are to be followed by the field technician to ensure that the monitoring program will produce valid, useful, and complete data. Procedures for proper equipment installation, operation, maintenance, calibration, and repair are also included. The following provides a glimpse of the quality control procedures.

The monitoring stations are checked at least three times per week. Specifically designed station check forms are filled out by the station operator during each station check. A bound logbook is maintained at each station for notation and narrative comments about the station operation. A logbook entry must be made whenever a station shelter is entered for any reason.

During each station check, each air quality analyzer is subjected to a zero and span check. In addition, precision checks are performed once every two weeks on all air quality instruments immediately after the instrument span check. Precision checks for TSP are performed by running collocated samplers at one monitoring site.

Multipoint calibrations of each air quality analyzer are performed monthly. Calibrations would also take place whenever station checks indicate the need for recalibration based on zero, span, and precision checks, or whenever the instrument's calibration is no longer valid due to repairs or servicing.

The requirements for calibration of air quality instruments have been specified clearly by the EPA ("Quality Assurance Handbook for Air Pollution Measurement Systems", Volume II, EPA-600/5/-77-027a, May 1977), while appropriate requirements for meteorological equipment are given in U.S. Nuclear Regulatory Commission Safety Guide 1.23. For some meteorological instruments, calibration standards have not been well-established and are thus based on past experience. The procedures are documented in the QA manual.

The gaseous standards used to obtain test concentrations for SO_2, NO, and CO are working standards certified by comparison to NBS Standard Reference Materials. Test concentrations for ozone are obtained by an ozone transfer standard which has been certified according to the NPA document EPA-600/4-79-056. All flow measurement devices are traceable to NBS-certified standards.

The sound level meter, used in the sound measurement program, will be calibrated before each day of measurements using a Bruel & Kjaer type 4230 sound level calibrator. This calibrator produces a tone at 94 $\pm$ 0.25 dB at 1 kHz. It will be crosschecked during quarterly audits against a reference calibrator, and if the difference exceeds 1 dB then it will be recalibrated by the manufacturer.

2.3.3 Samples of QA/QC Forms

Some of the forms currently being used to carry out the quality control and quality assurance aspects of the program are shown as Figures 2.3-1 through 2.3-4. A complete set of forms used for the monitoring program can be found in the Quality Assurance Plan.

AeroVironment Inc.
145 North Vista Avenue
Pasadena, California 91107

STATION CHECK LIST LOG

Project Number 139 Site WRSP Month _____ Year _____

Instrument	Item checked	Reference	Tolerance	Date							
Station	Time	MST									
	Temperature min/max	25°C	± 5°C								
	NO Cylinder pressure	>500 psi	Note pressure								
	CO Cylinder pressure	>200	Note pressure								
	Zero Air pressure	>200									
Calibrator Model Monitor Labs 8500 Serial No.	O_3 range - zero	off									
	O_3 range - span										
	O_3 flow										
	NO pressure										
	NO flow										
	CO_x flow										
	SO_2 flow										
	Filters										

Figure 2.3-1 EXAMPLE OF STATION CHECK LIST LOG

Project Number 139 Site WRSP Month _____ Year _____

Instrument	Item checked	Reference	Tolerance	Date							
NO/NO_x analyzer Model Monitor Labs 8440 Serial No.	NO flow	200	± 50								
	NO_x flow	200	± 50								
	O_3 flow	150	± 50								
	NO zero meter		.025 ppm								
	NO zero chart		± 5%								
	NO_x zero Meter		.025 ppm								
	NO_x zero chart		± 5%								
	NO span Meter		± 15%								
	NO span chart		± 5%								
	NO_x span Meter		± 15%								
	NO_x span chart		± 5%								
	Inlet filter	change	weekly								
	Fan screen	Check	Clean as necessary								
	Vacuum	20.5	± 1 in. Hg								
	Drierite	>1 in. blue	2 in. Blue								
	Span Set	Record when changed									
	NO	"									
	NO_x	"									
	Range	"									
	Time constant	"									

Figure 2.3-1 (continued)

Project Number 139 . Site WRSP Month _____ Year _____

Instrument	Item checked	Reference	Tolerance	Date							
SO_2 Analyzer TECO Series 43 Serial No.	Flow	2 scfh	±.5 scfh								
	meter zero		±.025 ppm								
	Chart zero		± 5%								
	Meter span		± 15%								
	Chart span		±5%								
	Inlet filter	change	weekly								
	Vacuum	10 in. HG	±1 in. Hg.								
	Fan screen	check									
	Span pot set	Record when changed									
	Zero pot set										
	Range set	"									
O_3 Analyzer Monitor Labs Model 8410 Serial No.	Sample flow		±5 cc/min								
	C_2H_4 flow		±50cc/min								
	Meter zero		±.025 ppm								
	Chart zero		± 5%								
	Meter span		± 15%								
	Chart span		±5%								
	Inlet filter	change	weekly								

Figure 2.3-1 (continued)

Project Number 139 Site WRSP Month _____ Year _____

Instrument	Item checked	Reference	Tolerance	Date							
Carbon Monoxide Analyzer Monitor Labs 8310 Serial No.	Sample Flow		.5 ℓ/min								
	Reference flow		.5 ℓ/min								
	Zero Chart		± 5%								
	Zero Meter		± 2.0 ppm								
	Span Chart		± 5%								
	Span Meter		± 15%								
	Input Sample	Change	Weekly								
	Converter Temperature		210°C								
	Conc. of CO Cylinder										
Data Logger	Paper Supply	Check									
	Printing	Check									
	Proper Time, Date	Check									
Particulate (TSP) Samplers	Change Filter	As Needed									
	Flow check	45 scfm	± scfm								
Facit Model 4070 Tape Punch	Punch Head Dust & Remove Chad										

Figure 2.3-1 (continued)

Project Number 139 Site WRSP Month _____ Year _____

Instrument	Item checked	Reference	Tolerance	Date							
Meteorological Equipment (10 meter)	Cups intact	normal									
	Vane intact	normal									
	WS comparison	normal									
	WD comparison	normal									
Meteorological Equipment (20 meter)	Cups intact	normal									
	Vane intact	normal									
	WS comparison	normal									
	WD comparison	normal									
Meteorological Equipment (30 meter)	Cups intact	normal									
	Vane intact	normal									
	WS comparison	normal									
	WD comparison	normal									
	Sigma Meter	working									
WS/WD Chart recorder (10 m)	Ink supply										
	Date										
	Zero										
EA Chart Recorder	Chart trace	clear									
	Chart supply	>20 feet									
Sample Manifold	Clean										
Sample Blower Fan	Working										
Technician's Initials											

MAINTENANCE RECORD FOR MONITOR LABS MODEL 8410E O_3 ANALYZER

Item	Maintenance Action			Frequency	Comments	Date Performed				Tech Initials
	Examine	Clean	Replace							
Chassis Fan			X	As necessary.	If noisy, replace.					
Chopper	X		X	Examine monthly; replace as necessary.	Observe chopper operation monthly. Check for smooth, free rotation, no wobble. Replace bearings as necessary.					
Chopper Motor	X		X	Examine monthly; replace as necessary.	Observe chopper motor operation monthly. Check for free rotation, no wobble.					
Chopper Drive Belt			X	6 months						
Sample Inlet Filter			X	Weekly		*	*	*	*	
Flowmeter	X	X		Examine 3 times per week; clean as necessary.	Ethylene Rotometers are inherently sticky. Clean only when float is completely frozen.					
Reaction Chamber	X	X		Examine 3 times per week; clean as necessary.	Examine by observing analyzer response time to zero and span checks. If response is sluggish, disassemble; clean with soapy water, then methanol, then dry with hot (40°C) air.					
Sample Pump	X		X	Examine monthly; replace as necessary.	Check that exhaust flow-rate is 300 ± 50 cc/min. Replace flapper valves and diaphrams if flowrate is low or erratic.					

*SEE CHECK LIST LOG

Figure 2.3-2 EXAMPLE OF INSTRUMENT MAINTENANCE RECORD

DATA OPERATIONS ACTION REPORT

Date Submitted:_____ Number_____

Data Operations

Project_____Site_____Component(s)_____

Period of Time Affected_____

Summary_____

_____

_____

_____

_____

_____See Back ☐

DO Action Being Taken_____

_____

_____

By:_____Date:_____DO Release:_____Date:_____

Please Return Before:_____

Action Personnel

Investigation Summary	Assigned to:	Initials	Date
Problem Cause(s)			
Action Taken/Proposed			
Preventive Measure(s) Taken/Proposed			
Effect on Data			

P.M.

DO Instructions:_____

_____

_____See Back ☐

Project Manager Approval:_____ Date:_____

FIGURE 2.3-3 EXAMPLE OF PROBLEM ACTION FORM

Summary cont._____

DO Instructions cont.:_____

FIGURE 2.3-3 (continued)

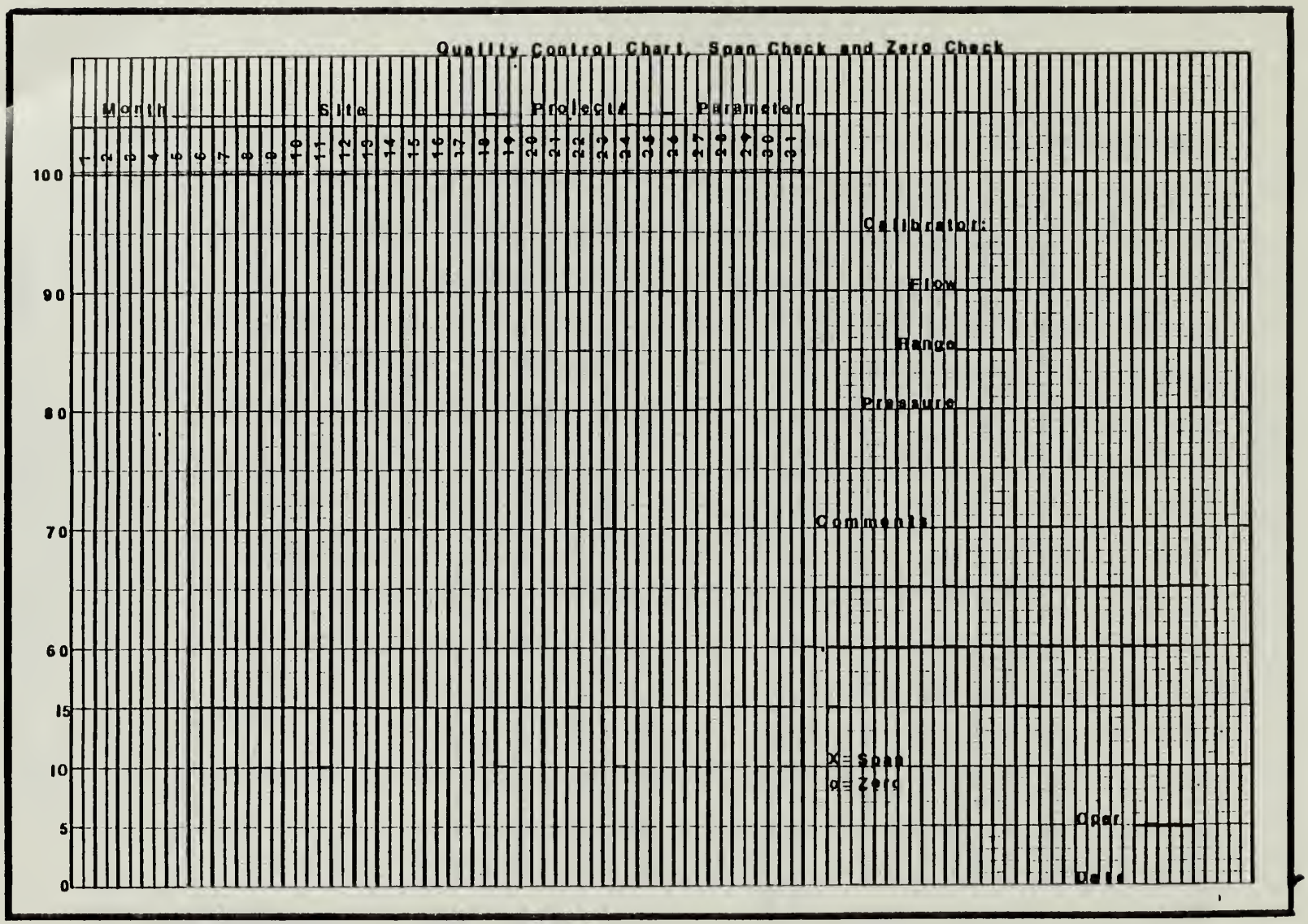


Figure 2.3-4 EXAMPLE OF QUALITY CONTROL FORM

2.4 Data Analysis

This section describes the data management approach and data analysis techniques that will be used on the collected data.

2.4.1 Data Management

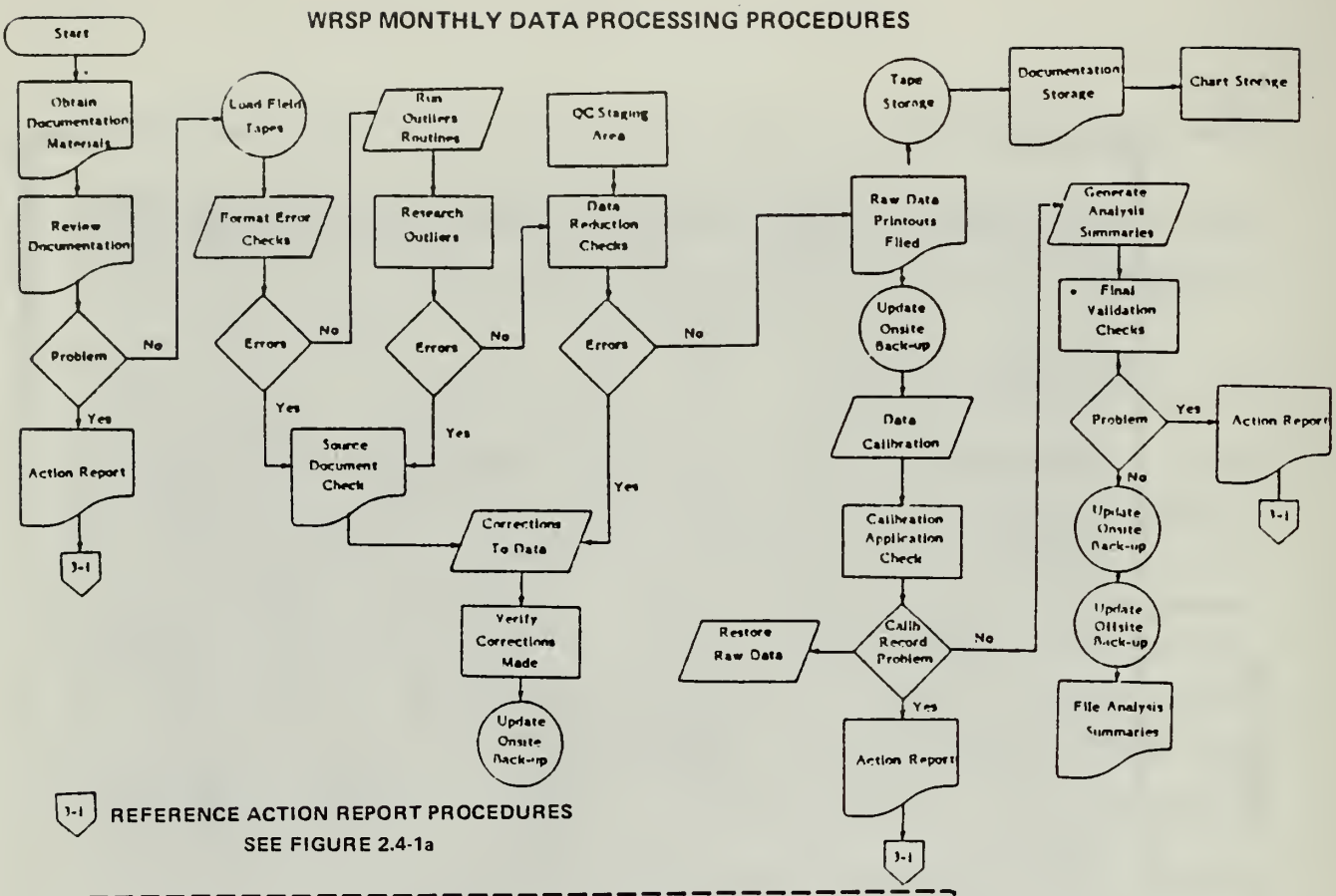
All the measurements described above, with the exception of the meteorological measurements at Sites A11 and A13, the particulate sampling and the contrast and mixing height measurements, will be recorded on computer tape, with backup recording on strip charts. Data from the records will be processed, edited, and calibrated to produce hourly, daily, monthly, and annual averages of each parameter, as appropriate. The chart records from the anemometers at Sites A11 and A13 will be digitized into a computer-compatible format, and will then be handled in the same manner. Figure 2.4-1 presents the data processing procedures for the Air Resources Monitoring program.

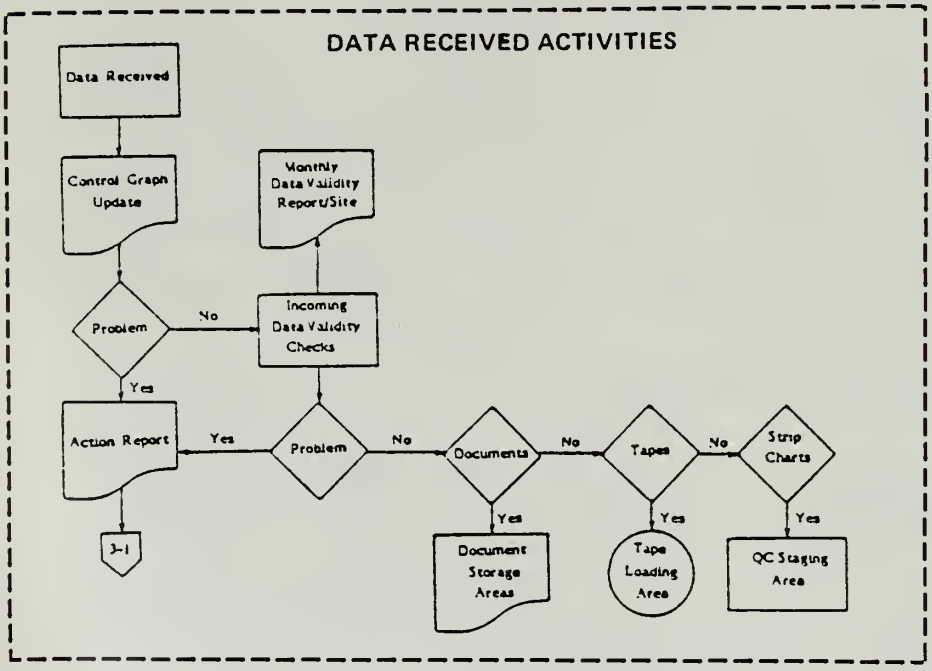
All the manually processed data will be merged with the computer tape data from the continuous sensors to form a complete air resources data base for subsequent analysis. The data will be stored on nine-track magnetic tapes with a density of 1600 BPI and will be coded in ASCII format. Data tapes will be submitted to the Oil Shale Office annually.

2.4.2 Statistical Analysis Techniques

The objectives of the program will be achieved if the following questions can be answered:

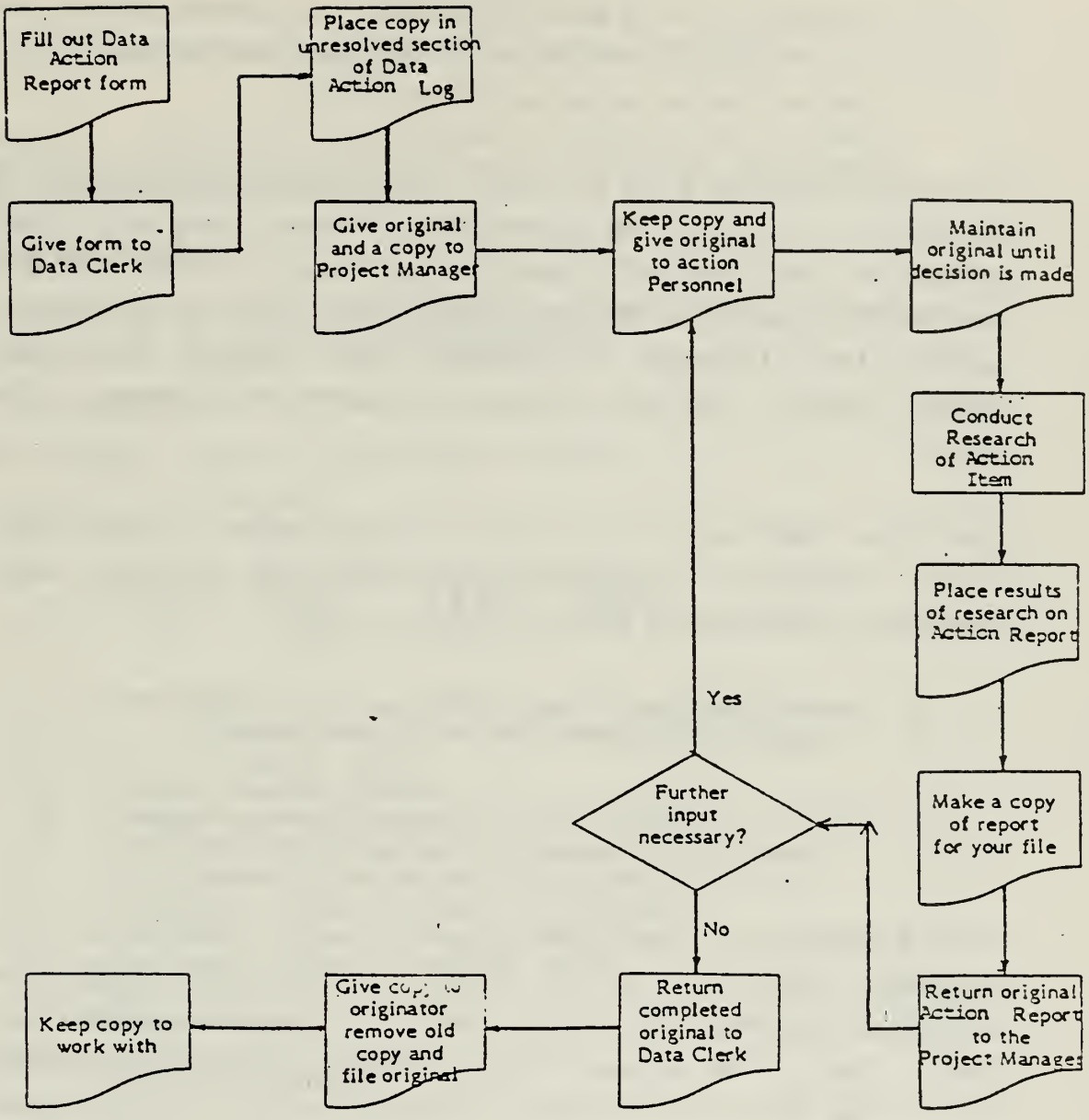
1. Do monthly and annual means of air quality, visibility, and meteorological parameters change over time? (For some parameters, the geometric mean or the total is the appropriate unit, in place of the monthly or annual arithmetic mean.).





DATA PROCESSING PROCEDURES FOR AIR RESOURCES MONITORING PROGRAM

FIGURE 2.4-1



DATA ACTION REPORTING FLOW

FIGURE 2.4-1a

2. Do hourly or daily means of air quality parameters differ from one site to the next, i.e., do Ua/Ub sources (or other nearby sources) influence the local air quality?

By answering Question 1, we will know if there are long-term changes in air quality, visibility, and meteorology. If indeed there are, further analysis will be conducted to quantify such changes. If the answer to Question 2 is positive, further analysis will also be necessary to quantify the differences, which would (for all gaseous pollutants) indicate impacts from the development or other developments in the area.

Statistical techniques will be used to provide answers to these questions. The two null hypotheses to be tested with statistical techniques that correspond to these two questions are:

H_0: There is no significant difference in the pollutant concentration before and during development

H_0: There is no significant difference in the pollutant concentration between various monitoring stations

These hypotheses will be tested at a 5% level of significance (95% confidence interval). Various methods will be used to test these hypotheses including the Z-test, Analysis of Variance (ANOVA), and Duncan's Test. The procedures test whether significant differences exist in the data. Descriptions of these and other statistical techniques can be found in "Guide to Statistical Problem Solving" prepared by Applied Science Associates for the Environmental Protection Agency (1975). An example ANOVA table is provided in Table 2.4-1.

Once the difference has been determined to be significant in testing the first hypothesis, this difference can be quantified simply by means of time-series analysis techniques. One simple time-series

TABLE 2.4-1

EXAMPLE OF ANALYSIS OF VARIANCE TEST (ANOVA)

Questions: On the basis of a 5% level of significance, are there significant differences between the means of SO_2 data collected at Site A4, A6, A10 and A14?

Define the hypotheses:

H_0: $u_1 = u_2 = u_3 = u_4$ where u_1, u_2, u_3 and u_4 are SO_2 means at A4, A6, A10, and A14 respectively

H_1: not all u's are equal

ANOVA approach: Level of significance = 0.05

$$SS_T = \Sigma x_i^2 - \frac{(\Sigma x_i)^2}{N}$$

$$SS_B = \frac{(\Sigma x_1)^2}{n_1} + \frac{(\Sigma x_2)^2}{n_2} \cdot \cdot \frac{(\Sigma x_n)^2}{n_n} - \frac{(\Sigma x_i)^2}{N}$$

$$SS_W = SS_T - SS_B$$

SS_T = sums of squares total
SS_B = sums of squares between
SS_W = sums of squares within
x_i = individual SO_2 value
N = total number of values in all samples
x_1 = individual values in sample 1 (A4 data)
x_x = individual values in sample 2 (A6 data)
x_n = individual values in the nth sample
n_1 = sample 1 size
n_2 = sample 2 size
n_n = sample n size
k = number of samples

Source	SS	df	MS	F
Between	--	k-1	SS_B/df	MS_B/MS_W
Within	--	N-k	SS_W/df	
Total	--	N-1		

Find critical value of F, using statistical table df = k-1, N-k

Decision: Accept H_0 if calculated F < critical value of F

analysis will be to pass the data through a low-pass filter using the Lanczos filter (Duchon, 1979). By filtering out all high frequency perturbations, the trends of evolution can be identified.

The Box-Jenkins time-series analysis technique can also be used to address the first question when several years of data exist for a given parameter. Because meteorological factors have such a significant effect on air pollution means, time-series analyses of air quality data are usually not informative unless more than ten years of data are available or unless the parameters being studied are changing rapidly. However, the data can be adjusted to correct for some meteorological factor in order to quantify trends over shorter periods.

The quantified answer to the second question is more easily obtained by comparing values at pairs of sites, in terms of their hourly or longer-term mean differences. Since the baseline data showed that most air quality parameter values did not vary over the study area, such comparisons will identify which stations are exhibiting impacts due to local sources, and what the magnitudes of these impacts are. Of course, the data have to be classified by meteorological categories to clearly identify the impacted sites for each category and to allow the impacts to be related to their sources.

TSP concentrations during the baseline period were not uniform from site to site, but rather reflected the effects of unavoidable local traffic and of localized meteorological variations. As was shown by Tombach and Chan (1977), the annual geometric mean of TSP concentrations was greater by a factor of two for those sites within 100 meters of existing roads than for those sites well-removed from roads. Thus, there was spatial variability in TSP concentrations during the baseline period. Such differences can be expected to increase once plant construction begins for Phase I. In most cases, the plant impacts on TSP levels are likely to be greater than baseline variations, so no ambiguity is expected about which sites are impacted by the Ua/Ub

developments. However, at the more remote sites, the historical background trends may be needed to evaluate whether any impacts are occurring.

2.4.3 Graphical Presentation of Data

Answer to the two questions in Section 2.4.2 can also be provided graphically. The following graphical representations will be performed:

- Plots of the time-series (in different averaging times) of concentrations)
- Cumulative frequency distribution plots
- Pollutant wind roses
- Plots of diurnal profiles of pollutant concentrations measured upwind and downwind of the plant

Examples of these plots are shown in Figures 2.4-2 through 2.4-6. The time-series plots will allow visual identification of trends. Cumulative frequency distribution plots will allow a comparison of measured data with standards. Pollutant wind roses will allow pinpointing the direction from which pollution is coming. Plotting concentrations measured upwind and downwind of a source will allow quantification of the impact at the down-wind station.

2.5 Contingency Plan

The data will also be evaluated to determine whether information being gathered is meeting its intended purpose. For example, if it is found that the measured wind seldom blows from the process area toward an intended impact monitoring station, then it may be appropriate to move

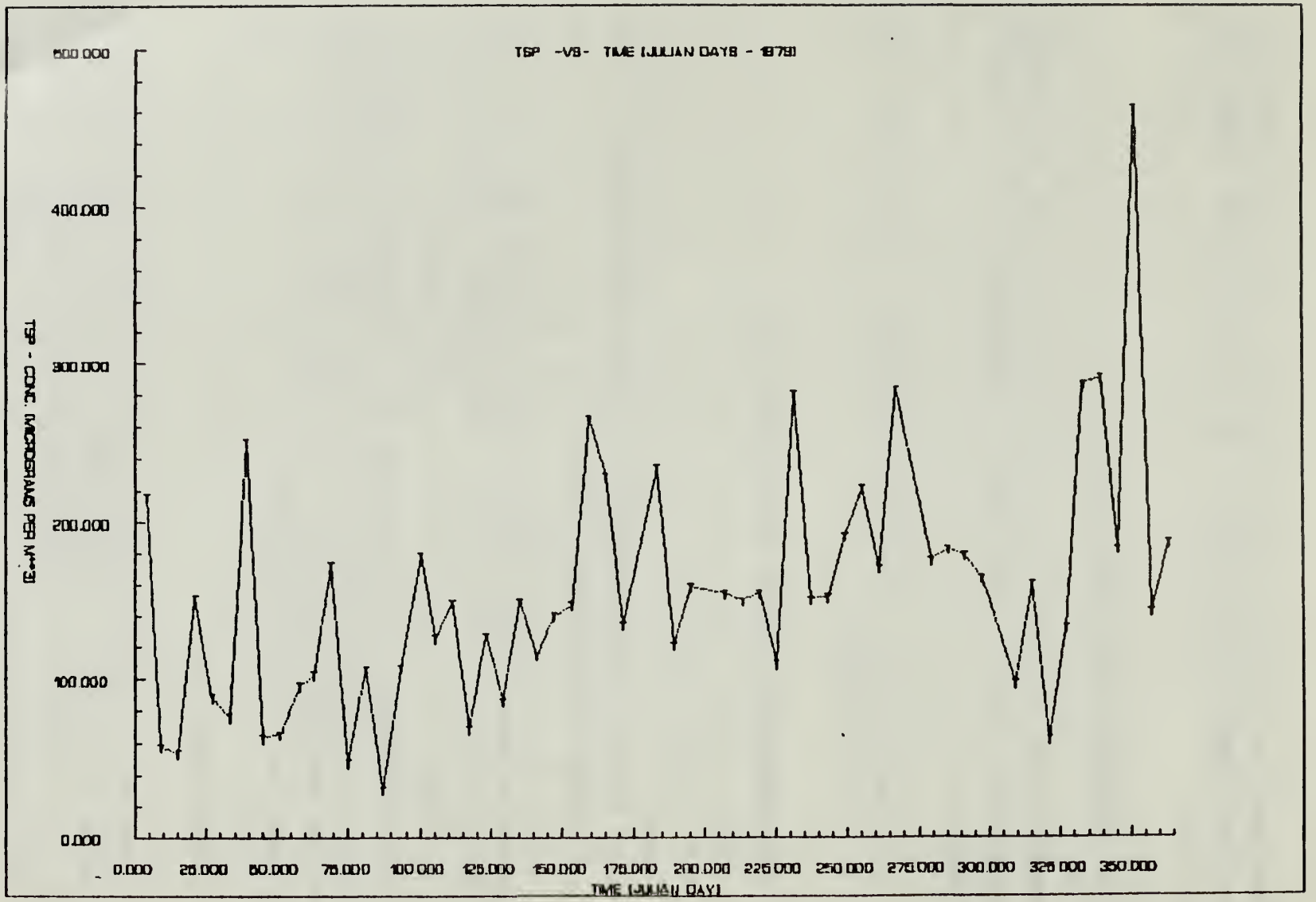


Figure 2.4-2 EXAMPLE OF DATA PRESENTATION: TREND OF 24-HOUR AVERAGED TSP CONCENTRATIONS MADE AT A MONITORING STATION (NOT WRSP) DURING A ONE-YEAR PERIOD.

Figure 2.4-3 EXAMPLE OF DATA PRESENTATION: TREND OF MONTHLY AVERAGE OZONE AT SITE A6 FROM 1975 TO 1979

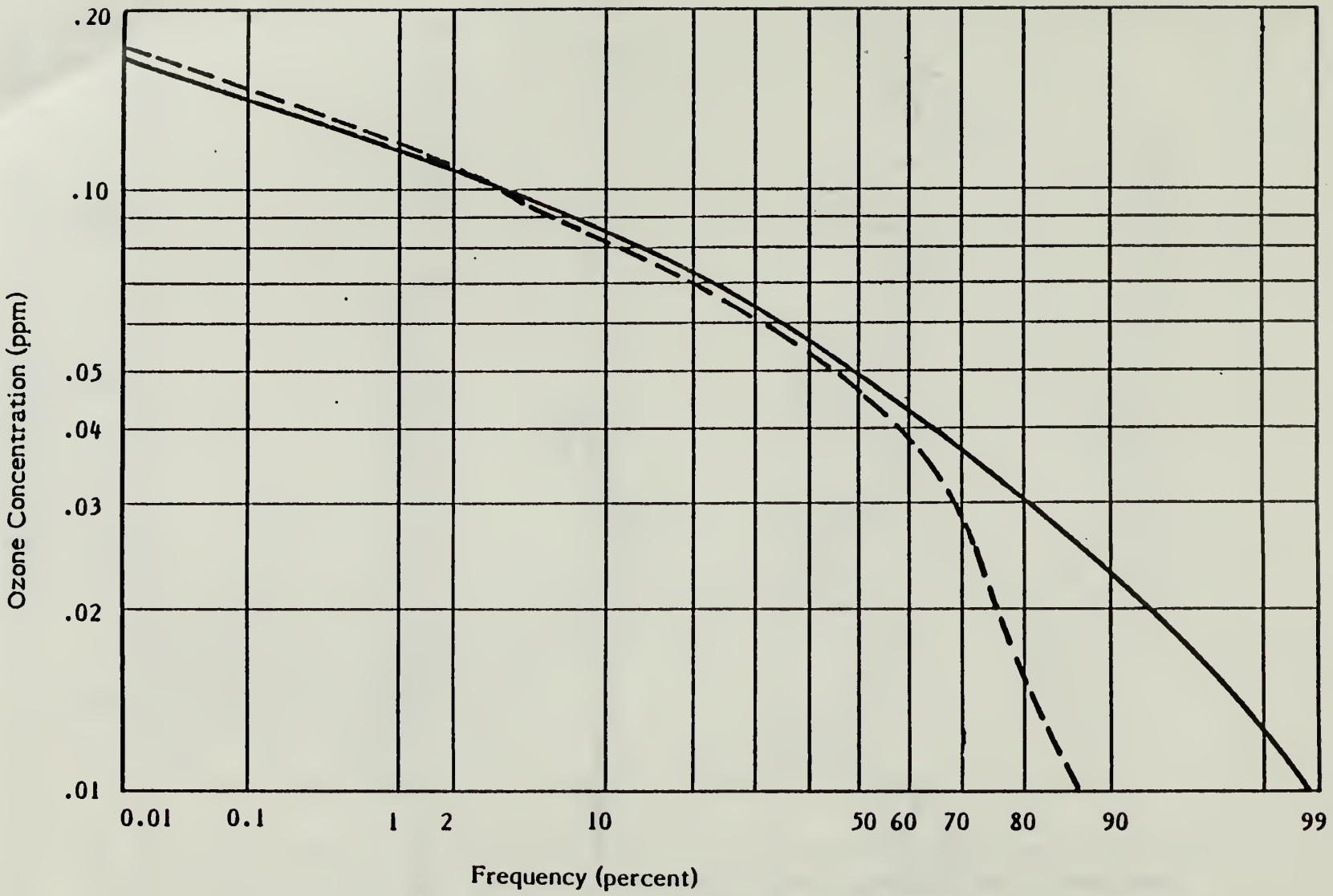


Figure 2.4-4 EXAMPLE OF DATA PRESENTATION: CUMULATIVE FREQUENCY OF EXCEEDANCES OF OZONE VALUES FOR MEASUREMENTS MADE AT TWO MONITORING SITES (NOT WRSP) DURING A ONE-YEAR PERIOD

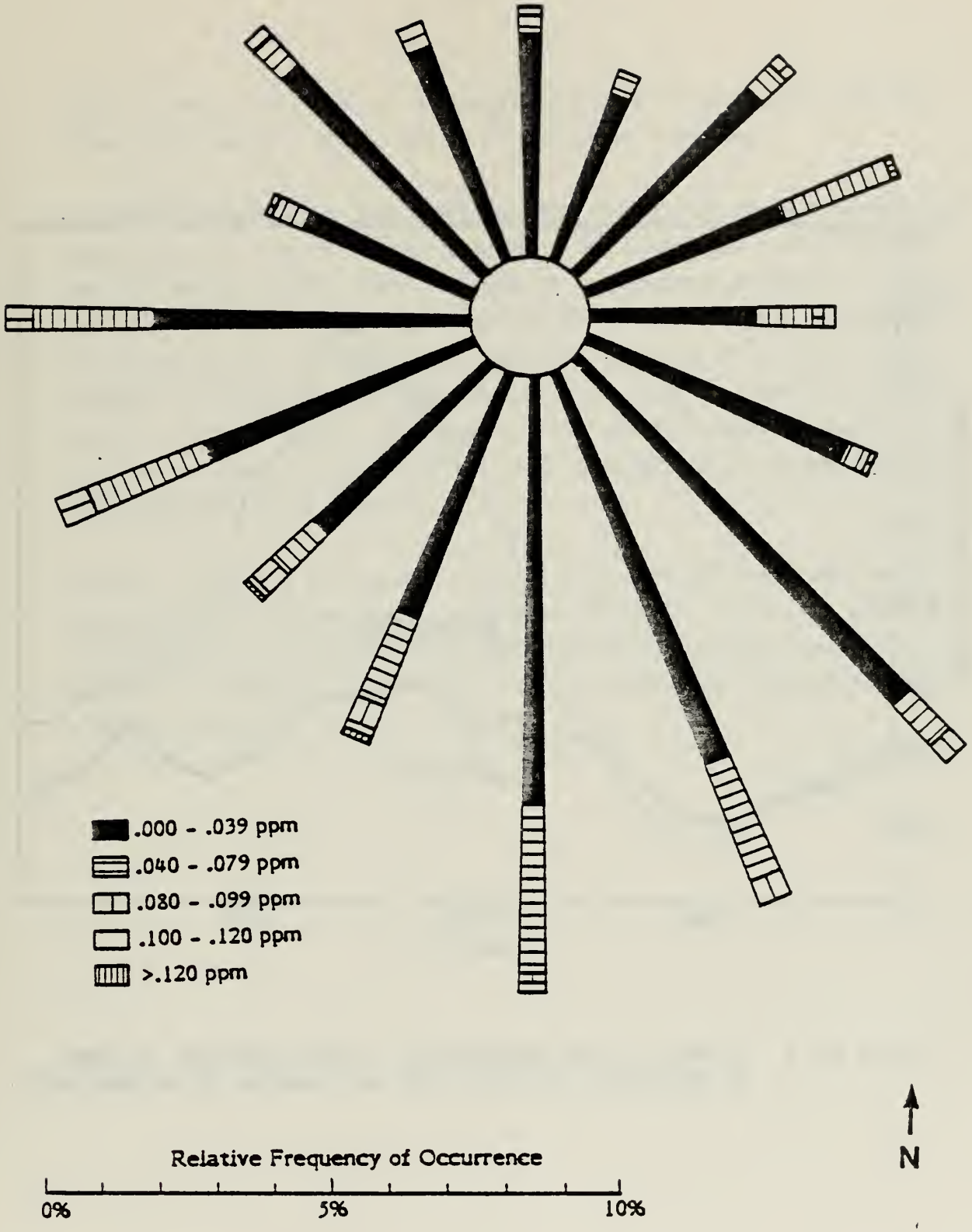


Figure 2.4-5 EXAMPLE OF DATA PRESENTATION: OZONE WIND ROSE (NOT WRSP)

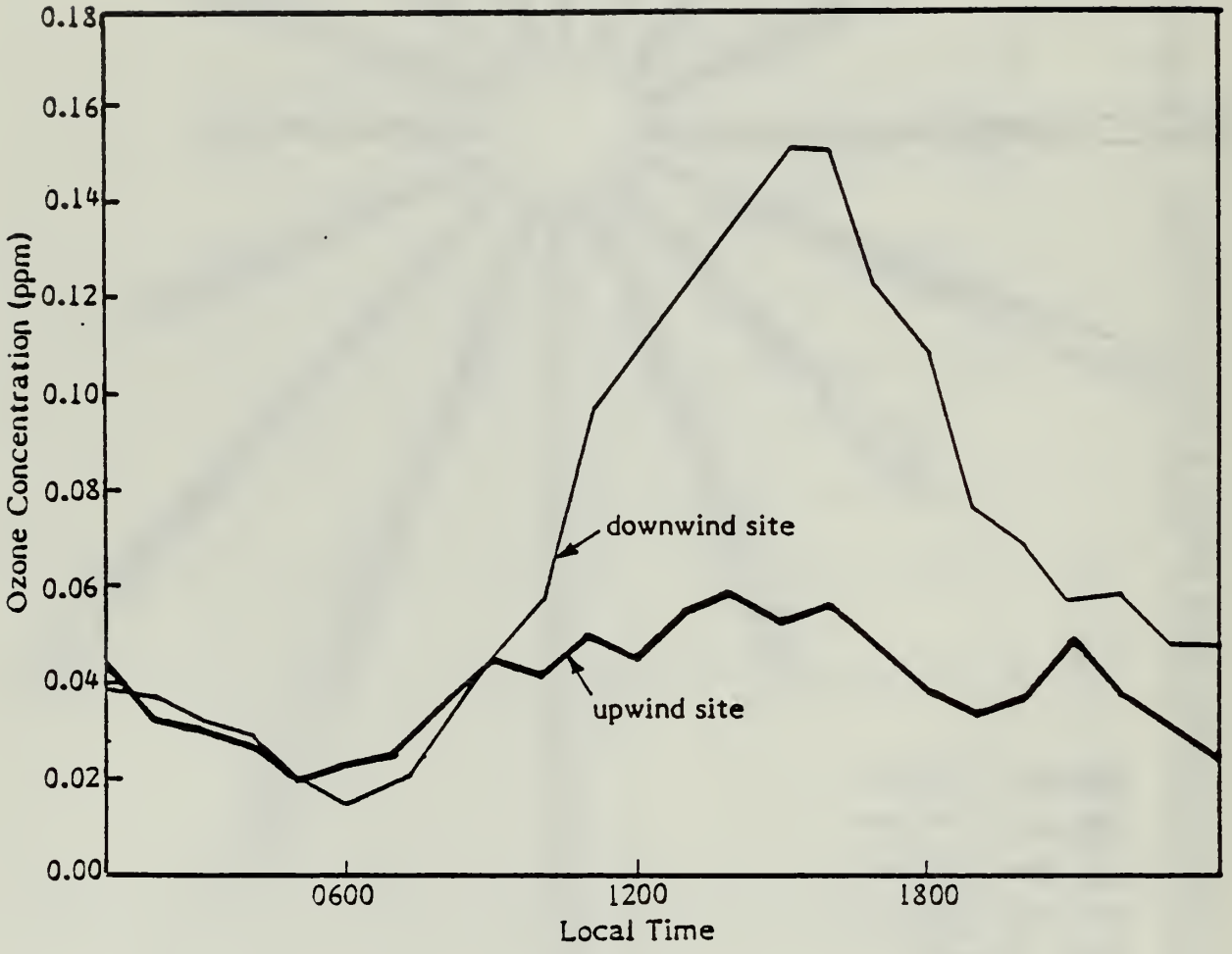


Figure 2-4.6 EXAMPLE OF DATA PRESENTATION: DIURNAL PROFILES OF OZONE AT MONITORING STATIONS UPWIND AND DOWNWIND OF AN URBAN AREA

the station. Similarly, if a background station shows regular impacts from local sources, it may not be in the proper location.

If there is doubt about the continuous monitoring data representing the background or impact levels properly, or about the probable peak impacts being missed, then a Group IV contingency program will be performed to clarify the actual situation and to identify the needed corrective action. Subsequently, after coordination with the Oil Shale Office, the EPA, and the Utah Bureau of Air Quality, the monitoring program will be changed, as needed. This could include the number or location of analyzers or stations, the frequency of measurements, or the parameters being measured.

Further, the field air quality monitoring program data will be coordinated with the planned source monitoring program. This will provide information on the success of our emission control programs and will be useful in determining the source of any identified adverse impact, should such occur.

REFERENCES

D. Allard and I. Tombach, "Evaluation of Visibility Measurement Methods in the Eastern United States," Technical Paper No. 80-29.3, Air Pollution Control Association, Pittsburgh, Pennsylvania.

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M.W. Chan and M.I. Smith, "Long-Term Variations in Ozone Measurements in a Remote Area in Northeastern Utah," Technical Paper No. 81-21.1, Air Pollution Control Association, Philadelphia, Pennsylvania.

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I.H. Tombach and D.W. Allard, "Intercomparison of Visibility Measurement Methods," JAPCA 30, 134-142, 1980.

I.H. Tombach and M.W. Chan, "Physical, Chemical, and Radiological Characterization of Background Particulate Matter in Northeastern Utah." Technical Paper No. 77-48.6, Air Pollution Control Assocation, Toronto, Ontario, Canada.

White River Shale Project Detailed Development Plan -- Oil Shale Tracts Ua and Ub.

3.0 VEGETATION

This vegetation monitoring section incorporates data from the baseline studies and the results of the analysis on the projected development activities for Tracts Ua and Ub in order to document existing conditions and determine interactions between the vegetation and the abiotic and biotic factors on the tracts. Previous data combined with continual monitoring provides for two important advantages:

- o documentation of vegetation responses to natural fluctuations or variation that could otherwise be interpreted as impacts of development;

- o the ability to identify problems early before they become serious. Thus, corrective measures or contingencies can be initiated prior to any irreversible environmental damage.

3.1 Program Design and Rationale: Objectives

The vegetation monitoring program is designed to provide data that describes the possible effects on the vegetation community caused by oil shale mining, processing and disposal of processed shale. The array of vegetation-related parameters used in monitoring includes key vegetation-related characteristics that are vital to ecosystem function. This stems from their sensitivity to immediate impacts of development or their response to cumulative influences plus interactions with affected ecosystem processes. The monitoring program includes variables that are indicative of environmental health and responsive to environmental impact.

The three main objectives of the vegetation monitoring program are:

- To document the existing vegetation conditions during and after various stages of development, including the range of variation exhibited temporally and geographically.

- To quantify plant responses to environmental impacts created by development, thereby allowing comparisons of plant responses in areas of little or no impact with those in areas of relatively high impact.

- To measure the success of revegetation techniques on the processed shale spoils and other areas that may be disturbed during operations.

The methodology used and data collection procedures outlined are based on an approach utilizing the scientific method. That is, the potential for an impact is recognized, and a possible explanation (hypothesis) is formulated. Subsequently, data are collected and analyzed, with the results being evaluated to determine if the hypothesis is verified.

The area of greatest impact to the vegetation in terms of area disturbed will be the processed shale pile. Revegetation techniques for the spoils are still being investigated and are discussed in the section on special projects (Section 7.2). Many of the parameters discussed below will be used in monitoring the shale spoils; however, it is anticipated that other parameters may be identified from the special revegetation studies that could be added to the vegetation monitoring program at a later date.

This monitoring program will be important in the identification of environmental impact. For instance, through examination of collected data, any apparent deviation from normal vegetation conditions would be identified. A wide deviation from an established norm for any

parameter may signal that an unusual condition has caused such a change. Causes of significant environmental change may then be identified by referring to other data available from the monitoring program and by applying appropriate statistical analyses. This allows normal variability to be separated from that caused by the project.

3.1.1 Response of Vegetation to Impacts

The White River Shale Project will affect all four vegetation types. The three major areas where existing vegetation will be displaced are:

- The site of the process facilities, where the bulk of construction activity will occur.
- The stockpile areas for coarse and fine raw shale.
- The processed shale disposal area (Southam Canyon).

Process facilities will be located in the northeastern portion of Tract Ua and the western portion of Tract Ub. The vegetation in the three major areas will, in effect, be removed from the local ecological system during the 25-year life of the project. The actual loss of habitat will be progressive, however, especially in Southam Canyon, and may be partially offset by the continuing restoration of disturbed lands and the vegetation of the processed shale pile.

The biological character of the process area and the Southam Canyon processed shale disposal area is essentially the same; both support mixed stands of sagebrush-greasewood and juniper vegetation types in roughly the same proportions. The project will have only a minor direct impact on the highly productive riparian habitat and the aquatic ecosystem. The riparian vegetation will, however, be affected by the installation and operation of water supply wells and pumps during Phase I. The area of shadscale vegetation will be reduced by the

installation of other project facilities, such as utilities, water and product pipelines, and access roads.

The potential indirect impacts on vegetation may include: waterborne and airborne pollutants, and altered grazing patterns by domestic and wild animals. Although desert plants are reported to be relatively resistant to airborne pollutants, recent studies suggest that plant communities within 20 kilometers of the process area may be affected. The presence of SO_2 in the concentrations expected may reduce plant germination and productivity in addition to causing accelerated leaf senescence, plant stress and reduced plant growth (Preston 1979). These effects will be measured by litter fall stress monitoring and sagebrush leader growth.

The composition of the plant community may also change through the loss of some species in the area of influence or merely changes in density or cover. Changes in the annual production of species may also occur. Due to the variable responses of plants to pollutants, the productivity of some species may increase while that of other species may decrease. The biomass of annual species will be monitored to assess this impact.

Waterborne pollutants may affect plants in two ways: (1) directly from pollutants taken up through the root system, and (2) through increased salinity of the soil. These effects will most likely occur in alluvial valleys that receive runoff and will be assessed during the analysis of plant chemical composition.

Species composition and productivity of the plant communities may also be affected by a reduction in the activity of soil microbes consequently affecting nutrient cycling and mycorrhizal associations.

Soil Microorganisms

Direct impacts on soil microorganisms could be highly localized. Since soil microbial activity is greatest near the surface and is associated with vegetative cover, the diversity and activity of the microorganisms will be reduced or curtailed whenever topsoil is turned, stored, or covered for any length of time. Localized direct impacts (i.e., habitat loss) to soil microorganisms occur in Southam Canyon as a result of deposition of processed shale. The existing soil in the canyon will be removed and used as a substrate in the processed shale revegetation program. The amount of time required for recovery depends on the degree of initial disturbances, subsequent disturbance caused by traffic and other activities, and the effects of the processed shale on the soil mixtures.

Soil microorganisms outside the Southam Canyon disposal area may be adversely affected by dust distributed by wind, and airborne emissions released by retorting, internal combustion engines, and steam generation. The effects of these impacts on important soil microbial processes and the role of soil microorganisms in influencing the long-term availability of pollutants to plants are largely unknown.

In addition, some trace elements have been reported to adversely affect soil/litter communities, causing possible changes in microbial processes. Due to important soil microbiotic-higher plant interactions, such changes may have significant effects on the structure and functioning of ecosystems.

Lichens

Because lichens and cryptogamic crusts are particularly sensitive to air pollutants, air emissions are likely to affect those organisms. Lichens and cryptogams hold soil particles and reduce erosion, increase soil fertility, and improve soil structure and water infiltration in desert ecosystems.

3.1.2 Parameters to be Studied

Those parameters selected for monitoring in the vegetation program represent characteristics that have relevance to the normal functioning of the plant portion of the ecosystem as well as to other major ecosystem components such as herbivores, soil microorganisms, and soil nutrients. The parameters chosen for study and criteria of selection are discussed below. A list of common and scientific names for species studied are given in Table 3.1-1.

Operational Parameters

Biomass of Annual Plant Species

This parameter is measured by harvesting the standing biomass of annual plants from a given soil surface area. Biomass of annual plants was chosen as a monitoring parameter because:

- It is an important source of herbage and seeds for animal feed.
- The resulting litter also serve to protect the soil from erosion and helps develop and maintain soil physical and chemical conditions.

A long-term consistent reduction in biomass of annual plants would have local ecological consequences. Conversely, it is important to monitor normal variation in biomass of annual plants, noting its relationship to weather and location factors. The monitoring program will identify and adjust for weather and location factors as causal agents in biomass fluctuation. Without adjustments for such factors, reductions in biomass production might be attributed to environmental impacts of development.

Table 3.1-1. List of scientific and common names for species that will be studied in the monitoring program.

Scientific Name	Common Name
Artemisia tridentata	Sagebrush
Atriplex canescens	Four-wing saltbush
Atriplex confertifolia	Shadscale
Atriplex cuneata	Castle valley clover
Bromus tectorum	Cheatgrass
Chrysothamnus greenii	Green's rabbitbrush
Grayia spinosa	Spiny hopsage
Hedysarum borealis	Northern sweetvetch
Juniperus osteosperma	Utah juniper
Oryzopsis hymenoides	Indian ricegrass
Salsola kali	Russian thistle
Sarcobatus vermiculatus	Greasewood

Sagebrush Leader Growth

Sagebrush leader growth is a linear measurement of the current year's twig/stem growth measured from the previous year's bud scale scars to the end of leaves at the tip of current growth. This parameter is not a direct expression of plant biomass or volume of growth but instead is an index of plant vigor, production, and general response to environmental conditions. Numerous ecologists have observed, and data gathered by WRSOC consultants on the tracts demonstrate, that sagebrush leader growth appears to reflect the general environmental conditions controlling growth (McArthur et al 1978, Barker 1981).

Sagebrush leader growth was chosen as a monitoring parameter because of its ease of measurement, the widespread distribution of sagebrush in tracts Ua and Ub, and the value of growth as an index of perennial plant function throughout the entire year. This index of shrub vigor is a key character of a dominant plant species on the oil shale tracts. Significant reductions in sagebrush leader growth would signal a serious and impending consequence to wildlife species dependent on the perennial vegetation for their food and cover. Sagebrush leader growth has been compared with other shrub leader growth and appears to be representative of those species studied.

Soil Chemistry

Several key soil-related parameters will be measured to characterize normal conditions and any deviations in soil microbiological processes. Those parameters chosen for monitoring include pH, electrical conductivity (EC), moisture, and organic matter content. These parameters are important because they exert such a dominant force in microbiological processes. West and Skugins (1978) advise monitoring such parameters in their review of nitrogen cycling in desert ecosystems. Whereas some parameters may show a prompt response (deviation from the

average) to an environmental perturbation, other parameters may not change quickly. Some parameters such as soil moisture, will indicate existing conditions when other parameters are monitored and evaluated together. Trace elements will not be monitored in the soil, rather such measurements will be made on plant tissues. Trace elements in the soil are important only insofar as they are taken up by vegetation.

Potential Parameters

Lichen Growth

Lichens represent a symbiotic association of a bluegreen alga and a fungus and are abundant on tracts Ua and Ub. Crustose and foliose lichens on rocks and sandstone cliffs are most obvious and are exposed to extreme ambient conditions. Lichens will be monitored because they may be among the first organisms to exhibit impacts of environmental perturbation because of their exposure on rock and soil surfaces (Brodo 1966, Denison and Carpenter 1973).

Litter Fall

The amount of litter returning to the soil is closely related to production of annual plant biomass. This parameter is measured under the canopy of the dominant shrubs and juniper trees and includes the litter fall from shrubs and perennial forbs as well as the litter from annual species.

This vegetation parameter was chosen based on the following criteria:

- The possibility that excess litter fall of leaves and twigs from shrubs and juniper may indicate undue stress on plants. (Excess litter fall has been observed in areas of air pollution.)

- o The fact that litter fall is essential to the normal functioning of many soil parameters and to many small animals.

The area around shrubs where the litter accummulates is the nutritional "storehouse" for arid plant communities (Garcia-Moya and McKell 1970, Bjierregard 1971) and any significant change in litter fall would result in changes in many ecosystem functions.

Plant Condition and Stress

Monitoring for plant condition and stress was chosen because it may provide an early warning that more serious consequences may occur if mitigation or alternative practices are not instituted. This parameter will be measured by means of remote sensing using infra-red (IR) photography. IR reflectance can indicate changes in plant condition and stress not evident under the visible light spectrum or from ground surveys. Numerical indices of stress will be developed for areas of abnormal reflectance values. The program will monitor changes in plant appearance and stress appearance relative to industrial development. If plant conditions change, more detailed analysis of causes such as root sectioning for sugar/starch content and stem testing will be conducted in the field.

Soil Microbiology

Several key parameters that describe the soil microbiology will be monitored. These are: total bacteria, total fungi, respiration and dehydrogenase activity. These parameters are indicators of the size and activity of the microbial community that exists within the soil.

Plant Utilization by Wildlife and Livestock

This parameter will measure the amount of herbage removed by browsing or foraging animals. This parameter is important because it indicates

the pressures that are exerted on the plants by wildlife and livestock. Since plants supply the food to primary consumers, excessive pressures may reduce plant vigor and increase mortality. Measurements may also be indicative of the palatability of the species over time. Measurements are made by estimating the amount or percentage of herbage removed in relation to the amount remaining (Heady 1975). Actual weight measurements can be obtained by using paired plots (fenced versus not fenced). Because many animal species depend on the vegetation for feed at different times of the year, it is not possible to attribute utilization to a given species.

Gross measurements of plant utilization along with biomass production were chosen for study because such measurements can be useful in guiding land management practices such as adjusting the numbers of grazing animals or interseeding and planting existing plant communities to increase production. A study of the success of interseeding was begun during 1981 (see Section 7.2). This program should be successful because of the artifically low level of productvity on tract due to post grazing practices.

Contingency Parameters

Plant Chemical Composition

Plant chemical composition is defined as the concentration of various chemicals in plant tissues. For purposes of monitoring, certain chemicals such as Na, N, S, Ca, K, B, Cd, As, Ni, Hg, Zn, Mg, Pb, N, Mo, F, Fe, and Se, are targeted for analysis. These elements were selected because they may be present in quantities greater than normally encountered as a result of industrial development. These chemicals may also accumulate to levels toxic to the plant or its consumers. Some of these chemicals have been identified as potentially toxic in studies by Kilkelly and Lindsay (1979) and by a review by the Office of Technology Assessment (1980). Sources of chemicals for plant uptake normally

would be from precipitated airborne effluents, leachate, or direct uptake from processed shale. These chemical analyses have been a part of the 1981 WRSOC monitoring program.

Soil Chemistry

If and when monitoring efforts indicate an impact of oil shale development upon the vegetation in tracts Ua and Ub, two sets of soil chemistry parameters can be measured to help define the nature and extent of that impact. Soil nitrogen analyses including assays for total N, NO_3-N, NH_4-N, NO_2-N, organic N, and C/N ratio will provide measures of the availability and rates of cycling of nitrogen. Baseline data for these parameters were collected during 1981. In addition, the total elemental composition of surface soils can be measured to define the atmospheric deposition and accumulation of metals and salts (e.g., Fe, Cu, Hg, Cd, Zn, Pb, Ni, Se, S, Na, B and As). Baseline analyses can be run on stored samples collected during 1981 and 1982.

Soil Microbiology

Mycorrhizal fungi and Rhizobium bacteria are beneficial soil microorganisms that enhance plant growth and establishment in most areas. Mycorrhizal fungi aid in plant uptake of phosphorus, trace metals, and water. Rhizobia, in association with legumes, fix atmospheric nitrogen. Populations of these microbes can be measured in White River tract soils as necessary to assess impacts of oil shale development and to monitor progress in the revegetation of the processed oil shale pile.

3.1.3 Sampling Locations

Selection of these sampling locations is based on five criteria:

1. Vegetation Types - As discussed previously, sampling locations were placed in representative stands of the four major vegetation types that were described in the baseline work on the oil shale tracts: sagebrush-greasewood, shadscale, juniper, and riparian.

2. Spatial Relationships - Sampling locations were selected so that they adequately survey tracts Ua and Ub. They were also located within reasonable distances to access roads to reduce time required for monitoring.

3. Control/Treatment - Sampling locations were selected so that some locations are more likely to be affected by potential impacts of oil shale development and others may not be impacted at all. The latter stations will serve as control sites for comparison purposes.

4. Location of Other Sampling Sites - Sampling locations are adjacent or identical to sampling locations used for other portions of the monitoring program in order that vegetation data can be correlated with other biotic and abiotic data.

5. Schedule of Development - Sampling locations were also chosen close to the development activities so that they will reflect potential impacts. Consequently, some of them will be removed by development activities and have to be relocated. Other locations will last the life of the project.

Sampling locations for most vegetation parameters included in this monitoring program were chosen at the beginning of the Environmental Baseline Study (White River Shale Project, Final Environmental Baseline Report 1977) according to general vegetation types. Vegetation types were mapped after an extensive reconnaissance of Tracts Ua and Ub. Figure 3.1-1 shows the distribution of the four major vegetation types:

sagebrush-greasewood, juniper, shadscale, and riparian. This map was the basis for plant community analysis and productivity sampling. It further serves as the basis for the continuing monitoring program.

Five representative sampling sites in each vegetation type were chosen. The number of sampling sites chosen was determined by feasibility and cost as well as general statistical adequacy. The site and sample numbering system employs the following notation: V = vegetation, G = sagebrush greasewood, J = juniper, R = riparian and S = shadscale. Within each sampling site, individual plots (denoted by Arabic numerals), are sampled in a random fashion. Thus a typical vegetation sampling site in the sagebrush greasewood type would be designated as VG-4. Sampling procedures which involve the removal of vegetation preclude using permanent locations because plot clipping affects subsequent year values.

All sampling sites and transects are shown on a map of the oil shale tracts (Figure 3.1-2). The schedule of monitoring and sampling location in relation to original sampling sites or proposed industrial area are summarized in Table 3.1-2.

Contingency soil parameters will be measured when necessary along the same transects and on the same schedules as the operational and potential soil parameters.

3.1.4 Sampling Schedule

Biomass Production of Annual Vegetation

Sampling of the annual vegetation biomass will be done in early June, which corresponds to the peak biomass of annual plants. However, vegetation and biomass will degrade or be lost due to a scattering of the seed or losses caused by wind blowing away materials, if done at a later date.

Ua

Ub

LEGEND

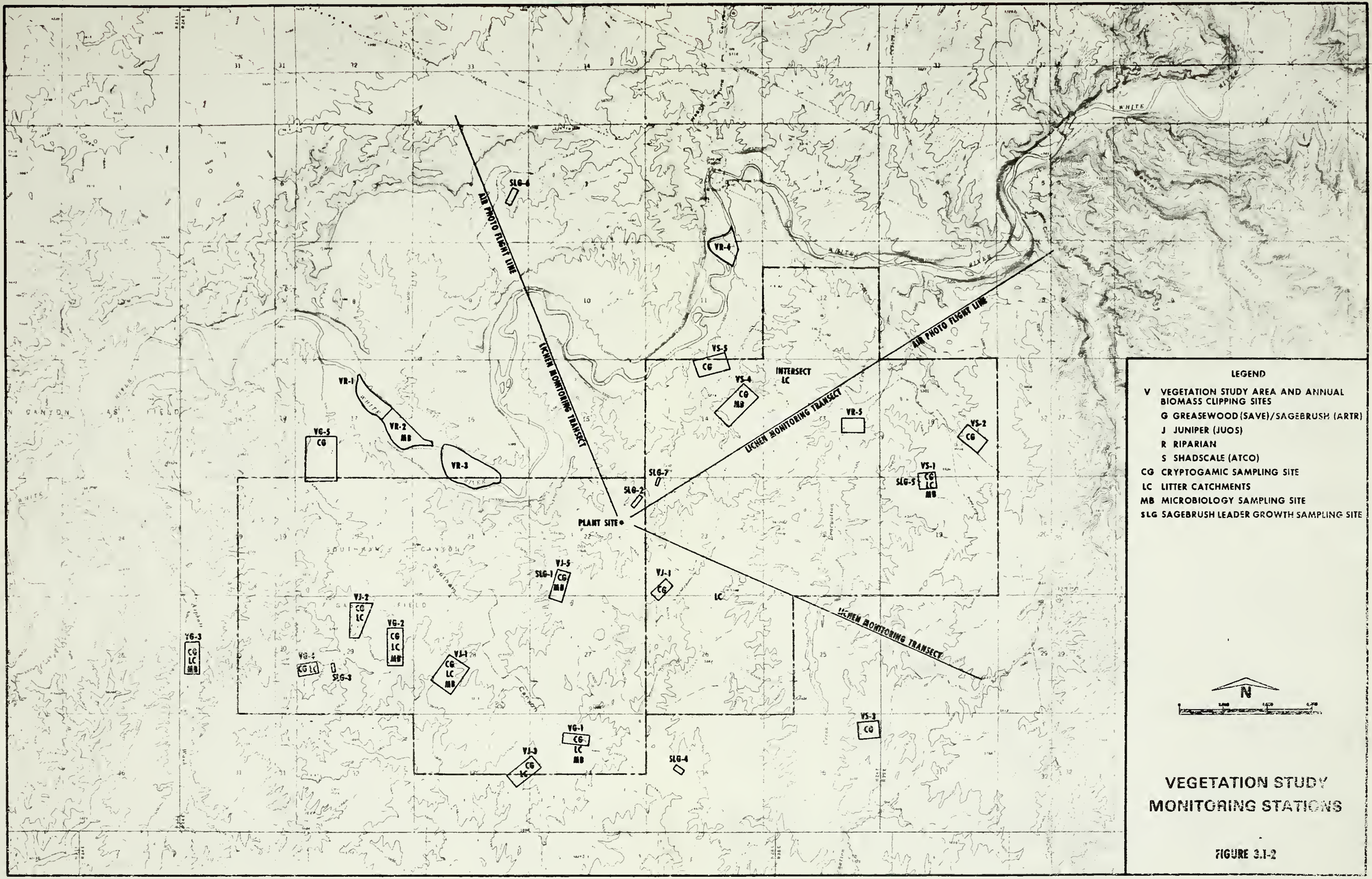
- 1 - SAGEBRUSH - GREASEWOOD
- 2 - JUNIPER
- 3 - SHADSCALE
- 4 - RIPARIAN

N

PHOTO MOSAIC; NOT TO SCALE

VEGETATION MAP

FIGURE 3.--1



LEGEND

- V VEGETATION STUDY AREA AND ANNUAL BIOMASS CLIPPING SITES
  - G GREASEWOOD (SAVE)/SAGEBRUSH (ARTR)
  - J JUNIPER (JUOS)
  - R RIPARIAN
  - S SHADSCALE (ATCO)
- CG CRYPTOGAMIC SAMPLING SITE
- LC LITTER CATCHMENTS
- MB MICROBIOLOGY SAMPLING SITE
- SLG SAGEBRUSH LEADER GROWTH SAMPLING SITE

VEGETATION STUDY MONITORING STATIONS

FIGURE 3.1-2

TABLE 3.1-2

VEGETATION MONITORING SCHEDULE

Parameter	Schedule for Monitoring	Location of Sample Sites
Biomass of annual plants	1st week in June *Bromus tectorum* hard seed stage	Each of original vegetation sampling sites
Sagebrush leader growth	1st week in October	Four sites each two miles E, W, N and S of industrial site, plus three sites close to industrial site
Soil chemistry	1st weeks of February, April, June, August, October, and December	Major vegetation and wildlife sampling sites distributed over tracts
Lichen growth	June and October	At selected vegetation sampling sites and areas within influence of industrial site
Litter fall	1st week in October before *Atriplex confertifolia* seed is ripe	Selected shrubs in the vicinity of main vegetation sampling sites
Plant condition and stress	Aerial photographic flight in June; field studies in July	Selected sites along the two principal wind directions in line with least expected effects from wind borne effluents
Soil microbiology	1st weeks of February, April, June, August, October, and December	Major vegetation and wildlife sampling sites distributed over tracts
Plant utilization	1st week in October	Exclosures located in areas of low and high expected utilization
Plant chemical composition	Samples taken from shrub leader growth in May and October	Sagebrush leader growth monitoring sites, processed shale disposal site

Sagebrush Leader Growth

Sagebrush leader growth will be sampled in early October after the summer growing seasons, consistent with previous year's sampling. Sampling is conducted during this period because it represents the peak growing season and yet is prior to the initiation of flowering stalks which would make sampling difficult.

Soil Microbiology and Soil Chemistry

Soils will be collected six times a year with sampling dates in early February, April, June, August, October and December. Soil chemistry and microbiology were added to the monitoring program in April 1981. Baseline data for these parameters are still incomplete and therefore relatively intense sampling schedules (six samples/year) will be maintained through 1982 and perhaps 1983. Once sufficient samples are obtained, sampling schedules will be reduced.

Lichen Growth

This task of the monitoring program will be conducted yearly during the month of June. Lichen growth is most abundant during the moist periods of the year so sampling will correspond to the end of relatively moist period and correspond to the sampling schedule for other parameters.

Litter Fall

Sampling for litter will be done yearly with samples gathered in October. October was selected because it represents essentially the end of the active growing seasons for most plants.

Plant Condition and Stress Monitoring Using Remote Sensing

Since vegetation stress may be a transitory phenonenon, it is important to schedule remote sensing activities to coincide with maximum stress periods. For example, if photography is conducted too early in the year before deciduous species have leafed out, faulty data and interpretation may result. Conversely, if photography is recorded too late in the season, natural senescence of deciduous vegetation may mask stress caused by gaseous effluents.

Because the best period to observe plant condition is expected to change from year to year, depending on weather conditions, it is planned that three overflights be synchronized with the phenology of dominant plant species. It is estimated that optimum time for photography will take place during the month of June or early July. However, this will have to be field verified according to the condition of vegetation at a given phenological stage of development. Therefore, field verification of stress areas will take place soon after the overflight (July or early August) so as to minimize the potential for change in the vegetation community.

Plant Chemical Composition

Samples used in determining plant chemical composition will be taken from shrub leader growth studies conducted in June and October. Plant chemical composition is not expected to change dramatically through the season so sampling will be coordinated with monitoring of other parameters.

3.1.5 Determination of Sampling Adequacy

The determination of sampling adequacy is important to provide a valid estimate of the inherent variability associated with the various parameters monitored. Unusually large sample size is required to

assess seasonal, locational and biological variability for some parameters at certain times. A field test for sample minimum size uses a preliminary subset of sample values according to the formula:

$$n_{MIN} = \frac{2s^2t^2}{L^2}$$

where:

n_{MIN} = minimum sample size required
s_2 = variance of sample
t = Table value (n-1 degrees of freedom, p = .05)
L = allowable error in the sample mean

A value less than p = .05 may be used depending on the difficulty and cost of increasing sample size, the risk involved in working at a lower level of precision and the consequences of making a decision error.

3.1.6 Fulfillment of Objectives

The objectives of the vegetation monitoring program are met by the proposed methods described in the following section. The parameters chosen for the study include characteristics that would respond in a short time to environmental perturbations as well as those that would reflect the cumulative effects of longer-term environmental impacts.

To meet the first objective of documenting the existing vegetation conditions during, and after various stages of development, data collected over Ua and Ub will be at the statistically specified level. Each of the parameters chosen will document standard conditions for vegetation functions ranging from biomass production, growth, litter fall, soil functions, plant appearance/condition, to chemical composition.

By locating sampling plots near areas proposed for industrial development and in remote areas away from industrial impact, it will be possible to make quantitative comparisons of plant responses under these two conditions. Further, by comparing baseline data to operational monitoring data it will be possible to detect if changes in vegetation have occurred as a result of development. Inherent variability in plant responses from year to year or season to season, poses a problem for sampling and statistical comparisons. Statistical techniques sensitive to this variability such as: analysis of covariance, t- and paired t-tests, step-wise multiple-regression analysis, and computer-based ecosystem analysis, will be employed.

The times chosen for sampling are key phenological and biological periods for vegetation functions. Plant responses at these times are either at peak or minimal levels. Further, the sampling activities are clustered to provide an opportunity to compare data sets and determine if correlations exist.

3.2 Methods

The methods and material needs for the tasks involved in the monitoring program are presented below. Many of the sampling methods are not unique but have been derived from the literature, which are cited for reference. The methods are designed, however, to be explicit and self-explanatory and should not require additional explanation.

3.2.1 Method of Data Collection

Biomass Production of Annual Vegetation

Biomass production will be sampled from each of the four vegetation types (shadscale, sagebrush-greasewood, riparian, and juniper). One transect will be located in each vegetation type. The transect will be 200 m in length, its origin will be located at random, and will

avoid the previous year's samples. The direction of the transect will be determined randomly. A 0.25 m^2 quadrat will be placed at 10-meter intervals along each transect. An estimate of annual plant cover will be recorded for each quadrat. Subsequently, all annual plants will be clipped at ground level and placed in paper bags. The bags will be permanently labeled with both the transect number and the quadrat number. The bags will then be transferred to the laboratory where they will be oven-dried at 25°C for 14 days and weighed on a Mettler 2000 balance or equivalent to the nearest 0.1 gm.

Sagebrush Leader Growth

Leader growth from one subspecies of sagebrush will be sampled from seven areas scattered throughout and adjacent to the oil shale tracts (Figure 3.1-2, SLG). Samples should be taken in early October so they are comparable with baseline data and with other years. At each site a starting point is randomly chosen but will avoid previous year's sampling. A 200-meter transect is sampled along a randomly chosen direction. Twenty points are located along this transect at 10-meter intervals. At each interval, the nearest sagebrush to that point is sampled by measuring 20 of the longest leaders from the current year's growth. The current year's growth can be recognized by the bud scars from the previous year. If there are fewer than 20 stems with new leader growth then zeros are entered into the data sheets. The plants are then flagged to avoid resampling the next year.

Soil Chemistry

Soils will be collected six times a year along eight transects. Three of the transects will be near the retort or along lines of prevailing winds from the retort (e.g., S4, R2, and J5). The remainder will be in relatively protected areas (e.g., G1, G2, G3, S1, and J1). Sampling dates will fall in early February, April, June, August, October, and December. On each date, six composite samples will be collected along

each transect. Three will be collected from the surface 5 cm of soil and three will be taken from the 5-15 cm depths. All samples will be taken beneath mature individuals of Artemisia tridentata. Each composite sample will be a mixture of soils collected from beneath two such shrubs; each will contain 1.0-1.5 kg of soil and each will be sealed in an individual plastic bag labeled with a sample number, transect number and soil depth. Samples will be kept in a cooler and returned to the laboratory immediately.

In the laboratory, soils are immediately sieved through a 2 mm screen and the coarse fractions are discarded. The sieved samples are thoroughly mixed and then split; half of each sample is sealed moist in a plastic bag and kept under refrigeration. The remainder is air-dried at room temperature. When possible all analyses are performed on these sieved soils.

In the event that soils are too wet to pass a 2 mm sieve, samples will be thoroughly mixed and split as above. Moisture analyses, bacterial counts, respiration assays, and dehydrogenase assays (see Soil Microbiology) can be performed on unsieved soils, if precautions are taken to avoid pebbles, stones, and bare roots in the aliquots. Air-dried subsamples will be sieved (2 mm) prior to analysis.

Organic Matter Content. The Walkley-Black method (Allison 1965) will be used. A 2-5 g sample of soil is ground, if necessary, to pass a 0.5 mm sieve. Avoid iron tools. An aliquot is tested for the presence of chlorides via reaction with $AgNO_3$. Note if a white precipitate is formed in a saturation extract. A 2 g sample of ground soil is then weighed into a dry 1/25 or 250 ml erlenmeyer flask. Five m of 0.167 M potassium dichromate is added and the flask is gently swirled. Next, 10 ml of concentrated sulfuric acid (10 ml of concentrated sulfuric with 25 g/l $AgNO_3$ if chlorides were detected above) is rapidly added. The flask is swirled immediately and placed on an asbestos pad and swirled again. The time is noted. After 20 $\pm$ 2 min, 50 ml of

distilled water are added. The flask is again swirled and allowed to stand for one hour. The contents are filtered (Whatman No. 2) and the color intensity of the filtrate is read at 600 nm with a reagent blank set at zero absorbance. Standards are used to plot a standard curve (absorbance versus organic carbon or organic matter content on linear paper) and sample organic matter contents are read off this curve. If absorbance is more than 0.50, results may not be valid.

Moisture Content. A 20 g sample of fresh soil is placed in an oven-dry, weighed soil tin. Tin and soil are weighed together, dried in an oven at 100°C, to constant weight, and then reweighed.

pH and EC. A 40 g sample of air-dry soil is placed in a 100 ml centrifuge tube. Forty milliliters of distilled water is added and the mixture is allowed to equilibrate with intermittent stirring for two hours. The suspension is then centrifuged (20,000 rpm for 10 minutes) and the supernatant is poured into a 50 ml beaker and analyzed on standard pH and EC meters.

Lichen Growth

Three major transects have been selected for monitoring the effect of effluents on lichen growth (Figure 3.1-2). Two transects will be established in the direction of the prevailing winds and a third control transect will be situated so that it is relatively free from plant emissions.

Plots will be established at seven intervals approximately 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0 mi. from the project facilities on each of the three major transects. At each plot, three measures of lichen performance will be evaluated:

1. A permanently marked plot (10 cm^2) will be photographed. Each plot will be marked on two opposite corners to ensure exact relocation.

2. Three samples of saxicolous lichen tissue will be collected for analysis as well as three samples of the lichen substrate. The lichen tissues will be returned to the laboratory for analysis. Lichen tissue will be analyzed in the laboratory for sulfur, fluorine, and aluminium. These three elements may adversely effect lichen growth. If other elements identified are potentially harmful, these may also be included at a later date. Soil or rock substrate on which the lichens are growing will be analyzed in a similar manner for the three elements listed above using standard analytical techniques.

3. Twenty quadrats will be sampled to assess lichen cover and frequency. These quadrats will be 2 cm x 100 cm and placed at two meter intervals along a permanently marked transect within each plot. This transect will then be 40 meters in length and marked on both ends with steel bars. Ocular estimates will be taken at each quadrat for lichen cover and frequency.

Litter Fall

To assess litter fall, litter traps will be placed under six species of shrubs and one tree species (A. tridentata, A. cansecens, A. confertiolia, C. greenii, G. spinosa, S. vermiculatus, J. osteosperma). The traps are semi-circular in shape with two halves combining to completely surround the plant. The traps have a 60 cm radius and are 15 cm deep and are placed directly beneath the plant umbrella to reduce error due to litter being blown into or out of the traps. The traps are made with 1/8-inch wire mesh which catches most of the litter but allows water to pass through to avoid decomposition of plant materials. A total of 30 litter traps for each of the seven species will be collected from the ten areas (Figure 3.1-2). Thus, a total of 210 litter traps will be sampled in October of each year. Contents are

emptied into a paper bag and the trap is then replaced under the same shrub. The bags are permanently labeled by site, plant species and number and stapled shut. The bags will then be transferred to the lab where they will be oven-dried for 14 days at 25°C and then weighed with a Mettler balance to the nearest 0.1 gm and the weight recorded. Litter traps may be used for several years as dictated by the results of current monitoring.

Plant Condition and Stress Monitoring Using Remote Sensing

Vegetative cover will be photographed from a fixed-wing aircraft. The resulting sequence of photographs, taken at predetermined altitudes and flightlines will constitute a transect that documents the condition of vegetation along that portion of the study area. Selection of the ground area to be photographed along the transect will be based on direction of maximum and minimum plume discharge from the retort and on the variations in topography and vegetative community types. This is shown in Figure 3.1-1.

Three eight-mile long transects will be flown within the study area. The first of these transects will be centered along the pathway of maximum plume effluent discharge from the retort. It will be flown at an altitude resulting in a scale ratio of approximately 1:2,000 (i.e., 1 inch = 2,000 inches). The actual scale of a given area may vary, especially in areas where topographic relief changes abruptly because of canyons and bluffs. The 1:2000 scale is considered optimal for detecting vegetative stress resulting from gaseous air pollutants.

The second transect will be oriented at approximately right angles to the first transect. It will also be at a scale ratio of 1:2000. It will be flown at the same altitude as the first transect and will traverse areas of similar vegetative community types. Transect No. 2 is expected to receive minimal or no gaseous discharge levels.

The third transect will be oriented along the same center line as in Transect No. 1., but will be flown at a higher altitude, resulting in a scale ratio of approximately 1:6000 (i.e., 1 inch = 6,000 inches). This third transect will cover a much larger area and has a scale acceptable for assessing other types of vegetation stress. This will enable correlation to the areas covered by other transects.

Photographic Specifications. The color infrared film to be used for the photographs will be Kodak Aerochrome Infrared Film 2443 (estar base). A Kodak Wratten No. 12 (yellow) filter or equivalent will be used to enhance color differences in the red and near infrared portions of the spectrum (500 to 900 nanometers). The forward overlap will be 60% to provide the specified steroscopic viewing conditions. Film will be processed to positive transparencies; these will then be encased in plastic sleeves for protection during the mapping phase of the study.

Only cameras with between-the-lens shutter will be used to maximize remote sensing capabilites for vegetation stress. A step wedge should be imaged on the film before processing. A step wedge is simply a series of known exposures on the leader or trailer of the exposed film or on a piece of the film cut from the roll, stored in the can, and shipped to the film processing lab with the exposed film for exposure of step wedge by the processing lab.

Delineation of Photographic Stress. Shortly after the film is processed it will be encased in plastic sleeves for protection and analyses. Each transparency should then be examined to delineate vegetation stress damage areas. Each area will be mapped by outlining the stress damage area with waterproof ink directly on the clear plastic overlays so as to preserve the integrity of the film.

Vegetation stress from disease, insects, weather, or other factors will be detected on the color infrared photography as areas lacking infrared reflectance from affected foliage. The reddish photographic

rendition of healthy vegetation (regardless of plant species) grades to magenta, purple, green, and yellow as the loss of infrared reflectance progresses due to increased stress. Areas of apparent vegetation stress will be noted on photo overlays and each assigned a reference number.

Field Verification of Vegetation Stress. During the ground reconnaissance, stress areas according to assigned reference numbers will be field checked for documentation. At least 70% of all stressed areas will be visited. If field visits reveal that the stress is uniform, widespread and relatively homogenous as to causal agent, less of the area (at least 30%) may actually require field visits.

Initially all assessments of vegetation damage will combine both subjective and quantitative measures of the severity and intensity of the damage. A coding system will be developed in the field.

Examples of damage codes to be developed will include:

- o identification of causal factor (when known)
- o estimates of the abundance or frequency of the causal factor
- o stratification of area into damage severity or intensity levels
- o counting of individuals affected
- o delineation of the aerial extent of the damage

As part of the stress documentation, color photographs and plant voucher specimens (or pest specimen) will be collected.

Should more quantitative methods be required, it is possible that techniques such as root sectioning for sugar/starch content and stem testing (shigometer) may be recommended. Such quantitative methods are costly and not merited at this early stage of the program, but are considered contingency parameters.

Soil Microbiology

Sampling, treatment and storage procedures are identical to those described for soil chemistry. The following parameters will be tested.

Total Bacterial Counts. Standard soil dilution and plating procedures are used to determine colony forming units (CFU) per gram dry soil (Clark 1965).

Dilution blanks containing 99 ml of autoclaved 0.1% peptone water are prepared in 250 ml screw cap erlenmeyer flasks. In addition, 9.0 ml and 9.9 ml blanks (autoclaved 0.1% peptone water) are prepared in screw cap culture test tubes. All transfers are made aseptically with sterile pipets.

Initially a 10^{-2} soil dilution is prepared by adding 1 g dry weight equivalent of fresh soil (field moisture content) to a 99 ml dilution blank. The flask is shaken in a 0.3 m arc for seven seconds and a 0.2 ml aliquot is then transferred to a 9.9 m blank (10^{-4} dilution). Two subsequent dilutions of 10^{-5} and 10^{-6} are then prepared. Each test tube should be mixed on a vortex mixer prior to sampling.

One milliliter aliquots of dilution are pipetted into individual sterile petri dishes containing autoclaved bacto plate agar (Difco). Each plate is swirled to ensure even distribution of the sample. Five replicates are run for each of the 10^{-3}, 10^{-5}, and 10^{-6} dilutions. Plates are incubated at 22°C. After five days, CFUs are counted with the aid of a Quebec Colony counter. Results are reported as CFUs per gram dry soil.

Direct Fungal Counts. Methods are adapted from Paul and Johnson (1977). A 5 g dry weight equivalent of fresh soil (field moisture content) is fixed in 10 ml of 4% formalin. Eighty-five milliliters of filter sterilized water (0.2 μ) are added and the suspension is homogenized in a high speed blender for five minutes.

One milliliter of analine blue stain (0.1% [wt/vol] in 0.2 M K_2HPO_4, pH 8.0 (filtered to remove particulates) is placed in a 5 ml test tube. A 0.05 ml aliquot of the soil homogenate is added directly to the stain and the mixture is allowed to stand. After 30 minutes, 10 ml of filter sterilized water is added and the suspension is filtered down onto a 0.4 um nucleopore filter disc. The disc is transferred to a microscope slide and allowed to dry in a covered box. One drop of immersion oil is placed on the center of the filter and a 25x25 mm cover slip is added. The immersion oil should be bubble-free, should flow over the entire soil field, but should not displace soil particles. Fungal lengths are measured with an ocular micrometer at 400 power under an epifluorescent microscope. A suitable blank prepared with all reagents but no soil is run in parallel. Two filters are prepared per soil sample. Total hyphal length per gram of dry soil is calculated using appropriate conversion factors.

Respiratory Activities. Rates of CO_2 evolution are measured using methods of Elican and Moore (1962). The incubation vessel for measuring CO_2 evolution consists of a 125 ml screw cap (or other air-tight enclosures) erlenmeyer flask with a center well (diameter 1.5 cm, height = 4 cm).

Ten grams of soil are placed in the bottom of the flask around the center well. A 1.0 ml aliquot of a 0.04 N $Ba(OH)_2$ solution is pipetted into the empty center well. Three controls are run with each batch of 48 samples. They consist of flasks with the Ba $(OH)_2$ solution in the center well and no samples.

Replicate analyses are run with every tenth sample to measure precision of the analysis. Flasks are capped immediately following the addition of Ba $(OH)_2$. They are the incubated at 30°C in a gently shaking water bath or on a shaker table in an incubator. After 1.5 hours, flasks are uncapped immediately, and the solution in the center well titrated with 0.02 N HCl dispensed from a microburette. The endpoint is reached

when the salt in the center well is dissolved. Phenolpthalein indicator is added to aid in endpoint detection, if necessary. The amount of HCl is recorded.

The mean amount of HCL titrated for the blanks is subtracted from results obtained for samples. The following calculations are used to determine meq CO_2/g dry soil/hr:

1) ml HCL x 0.2 = meq CO_2

2) $$\frac{\text{meq } CO_2}{\text{g dry soil x 1.5 hr}} = \text{meq CO2/dry soil/hr}$$

Dehydrogenase Activity. Techniques of Casida et al. (1964) are used in revised form. For each sample, individual 6 g dry weight equivalents of fresh soil (field moisture content) are added to each of three 15 ml screw cap test tubes. Two tubes serve as replicates. The third serves as a blank. Next, 2.5 ml of sterile distilled water are added to the blank. One milliliter of a 3% aqueous solution of 2, 3, 5 triphenyltetrazolium chloride (TTC) is then added to each of the two replicate tubes.

Tubes are tightly capped, mixed on a vortex mixer, and incubated for exactly 24 hours at 30°C. After 24 hours, the contents of each test tube are transferred with the aid of methanol (100%), to a funnel plugged with non-absorbant cotton. The filtrate is collected in a 100 ml volumetric flask. Additional methanol is poured through the funnel until the reddish color is removed from the cotton plug. The filtrate is raised to a volume of 100 ml with the methanol.

Each flask is shaken to assure uniform color throught the sample. Percent transmittance (% T) is determined at 485 nm in a Spec 20. 100% T is set with a flask prepared for each sample prior to determining transmittance for the respective replicates. Concentration of formazan is determined from a standard curve. Soil dehydrogenase activity is expressed as mg formazan/ml/day.

Plant Utilization by Wildlife and Livestock

Plant utilization will be determined by the Cole browse survey method (Cole 1963). Utilization is determined by counting the number of browsed and unbrowsed twigs and calculating the percentage of twigs utilized.

Permanent transects will be established in each vegetative type and will census each shrub species that commonly occurs. Shrubs which will be monitored for animal use include A. tridentata, A. confertifolia, A. cuneata, C. greenii, and S. vermiculatus. Shrubs within a vegetative type will be selected through the closest plant technique until 25 plants of each selected shrub species on the site have been surveyed. The following measurements will be made on each browse transect:

1. Form Classes
   - all available, not hedged
   - all available, lightly to moderately hedged
   - all available, severely hedged
   - partly available, not hedged
   - partially available, lightly to moderately hedged
   - partially available, severely hedged
   - unavailable
   - dead

Availability is gauged for snow conditions and height. Hedging is based upon the length and appearance of the two-year old wood immediately below the current leaders.

2. Age Class
   - seedling, 1/8-inch or less in diameter
   - young, 1/8- to 1/2-inch in diameter
   - mature, over 1/2-inch in diameter
   - decadent, 25% or more of crown dead

3. Leader Use Estimates

   Leader use estimates or counts are based on the percent of total available leaders showing use. Twenty leaders are sampled per individual to determine the percent usage.

4. Growth Index

   Ten ungrazed twigs on the available portion of each plant will be measured. This index provides a means of comparing growth between years, and is also an indicator of vigor.

Plant Chemical Composition

Plant samples for chemical analysis will be obtained from three areas. At the outset, replicated samples will be taken in May and October from two shrubs (Artemisia tridentata and Grayia spinosa), two grasses (Bromus tectorum and Oryzopsis hymenoides), and two forbs (Hedysarum boreale and Salsola kali). In each group, one of the species matures early and the other matures late.

Plant materials or current season litter will be used for standard laboratory analysis for the following parameters: SO_4, NO_3-N, Na, Mo, Ca, K, Mg, B, Cd, Zn, As, Hg, Pb, Ni, F, Fe, Se, and any other elements that appear to be a potential hazard.

Soil nitrogen analyses will be performed using standard techniques outlined in Black (1965). Total elemental compositions of soils will be determined using hydrofluoric acid digestions and standard analytical methods (Black 1965). The abundances of mycorrhizal fungi and Rhizobium bacteria will be determined through greenhouse bioassays employing the most probable number techniques (Porter 1979).

3.2.2 Material Needed

Biomass Production of Annual Vegetation

Equipment needs are minimal for this aspect of the vegetation monitoring. Field supplies needed include clippers, framed 0.25 m^2 quadrats, flagging, and paper bags and permanent markers.

Laboratory equipment needs are a drying oven and a Mettler balance or equivalent.

Sagebrush Leader Growth

Equipment needed for this aspect of the vegetation monitoring consist of transect tapes (200 meter), clippers, calipers and flagging.

Soil Chemistry

Equipment needed for the soil chemistry include: sample bags, cooler, 2 mm slides, drying oven, 0.5 mm sieve, spectrophotometer, erlenmeyer flask, chemicals ($AgNO_3$, sulfuric acid, potassium dichromate), centrifuge, centrifuge tubes, pH meter, solu-bridge for EC measurements.

Plant Utilization

Equipment needed for this aspect of the monitoring program is calipers, flagging and permanent stakes or markers to locate the starting point of each browse transect.

Litter Fall

Field equipment needed for this task are 210 litter catchments, paper bags, permanent markers, calipers, and flagging.

Laboratory equipment needs include a drying oven and a balance for weighing the litter.

Plant Condition and Stress Monitored by Remote Sensing

Materials required during the stress monitoring include:

- o Aerial Photography (to be completed by subcontract)
- o Stress Delination
  - plastic sleeves (one for each transparency)
  - marking pens
  - light table
  - stereoscope
  - labels and folders
- o Field Verification
  - camera and colored film
  - plant press and plastic collection bags
  - labels
  - hand lens

Soil Microbiology Equipment and Materials

- o Sampling
  - plastic bags, one liter
  - ties
  - marking pens
  - notebook
  - soil core extractor, 5 cm diameter, greater than 15 cm long
- o Sample Preparation
  - soil sieve, 2 mm
  - refrigerator
- o Moisture Content
  - drying oven
  - soil tins
  - balance accurate to 0.01 g

- pH and EC
  - balance accurate to 0.01 g
  - pH meter accurate to 0.01 pH units
  - EC meter accurate to 0.01 mm hos/cm
  - centrifuge tubes, 100 ml
  - centrifuge capable of spinning 100 ml tubes at 2,500 rpm
  - graduated cylinders, 100 ml
  - beakers, 50 ml
  - pH buffers, pH 4.00, 7.00, 10.00

- Organic Matter Content
  - balance accurate to 0.01 g
  - non-ferrous soil grinder
  - soil sieve, 0.5 mm

- Direct Fungal Counts
  - balance accurate to 0.01 g
  - formaldehyde
  - millipore filter funnels, 47 and 25 mm
  - millipore filters, 0.2 um, 47 mm diameter
  - nucleopore filters, 0.4 um, 25 mm diameter
  - filter flasks, 250 ml and 1,000 ml
  - vacuum pump
  - homogenizer or high-speed blender
  - homogenizer flasks, 150-200 ml
  - timer
  - analine blue
  - potassium phosphate, dibasic
  - test tubes, 5 ml
  - test tube racks
  - pipettes, 1 ml
  - micropipettes, 0.05 ml
  - microscope slides
  - cover slips 25 mm x 25 m, 1.5 mm thickness
  - immersion oil, non-fluorescent
  - epifluorescent microscope with mercury lamp, 07
  - Zeiss filter assembly 10 and 40 x objectives, 10
  - eyepieces, and ocular net micrometer

- Respiratory Activities
  - screw cap flasks with center well, 125 ml
  - balance accurate to 0.01 g
  - silver nitrate
  - flasks, 125 or 250 ml
  - potassium dichromate
  - sulfuric acid
  - asbestos pads
  - timer
  - distilled water
  - filter funnels

- Whatman No. 2 filter papers
- spectrophotometer
- spectrophotometer cuvettes
- test tubes, 30 ml
- rack for 30 ml test tubes

o Total Bacterial Counts
- autoclave
- peptone extract
- distilled water
- screw cap flasks, 250 ml
- pipettes, 0.1, 1.0 and 10.0 ml
- transfer hood
- balance accurate to 0.01 g
- graduate cylinder, 100 ml
- vortex mixer
- petri dishes
- bacto plate count agar
- incubator, 22°C
- Quebec counter
- distilled water
- barium hydroxide
- pipette, 1.0 ml
- incubator, 30°C
- shaker table
- hydrochloric acid
- microburette
- phenolphthalein

o Dehydrogenase Activity
- balance accurate to 0.01 g
- screw cap test tubes, 15 ml
- distilled water, filter sterilized
- 2,3, 5 triphenyltetrazoleum chloride
- vortex mixer
- incubator, 30°C
- methanol, 100%
- filter funnels
- absorbent cotton
- volumetric flasks, 100 ml
- spectrophotometer
- spectrophotometer cuvettes
- triphenylformazan

Lichen Monitoring

Equipment needed for this aspect of the vegetation monitoring will include:

- o Photographic Record
  - 35 mm camera
  - tripod
  - film
  - quadrats
  - permanent stakes
- o Tissue and Soil Sampling
  - muffle furnace
  - chemicals
  - digestor
  - atomic absorption spectophotometer
  - glassware and tritrator for colorimetric tests
- o Assessing Lichen Cover and Frequency
  - permanent stakes
  - 40-meter tape measure
  - quadrats
  - flagging
- o Plant Chemical Composition
  - standard analytical laboratory instruments, glassware and reagents

3.3 Quality Assurance/Quality Control (QA/QC) Procedures

3.3.1 Quality Assurance (QA) Program Design

An important aspect of the proposed project will be the Quality Assurance/Quality Control Program. The best quality assurance is that of having only trained and qualified professionals gathering the data. When necessary, quality assurance audits will be performed to verify data collection and analysis procedures. The data will also be duplicated and checked as soon after sampling as possible to avoid any missing data due to lost data sheets. Original data sheets will be placed in the project file for the duration of the project. In

addition to the hard copies, the data will be filed onto a computer disc or tape. All field collections will be permanently and correctly labeled. Data and field collections will be checked daily by the field coordinator to ensure that the information is labeled and gathered correctly.

3.3.2 Quality Control Procedures

The field procedures for the vegetation monitoring require no extensive instrumentation that would require calibration. Most of the data gathered involve taking measurements of length with calipers or rulers and the collection of plant materials via either litter catchments or clippings within the 0.25 m^2 quadrats. These measurements again will be checked daily.

Laboratory instruments will be checked for accuracy. Balances will be checked and calibrated prior to any weighing and on a daily basis as needed. Chemical analyses for both the vascular plants and the lichen tissue will be duplicated to ensure quality control. Approximately one-tenth of all samples will be split for duplicate analysis.

Photographic equipment will be carefully checked to ensure that photographic products are comparable among different years. Cameras will have the capability to image the altitude, time of day, and other pertinent information directly onto each frame.

Soil analyses for moisture content, pH, EC and organic matter content will have duplicated samples to insure quality results. Standards will also be used to check the pH, EC and organic matter analyses and insure proper calibration of equipment. Every tenth respiratory and dehydrogenase analysis will have a replicate sample analyzed to measure the precision of the techniques used.

Senior personnel will supervise and monitor all operations to insure that the data are accurate.

3.3.3 Examples of Data Sampling Forms

Examples of data sampling forms are shown in Figures 3.3-1 through 3.3-5.

3.4 Data Analysis

3.4.1 Data Management

Data sampling forms will be checked in the field daily and will be duplicated the same day or as soon as possible. This will facilitate making corrections or filling in deletions. The raw data will then be transferred to computer tape or computer disks in the laboratory for data summaries, analysis, and storage. The hard copies of the data forms will also be stored as a backup to the computer tape.

3.4.2 Graphical Interpretation and Analysis

Graphs will be used to show trends in vegetation monitoring such as X-Y analysis, bar graphs, and mean separation graphs for ANOVA. Much of the summary information will be displayed in tables, however, specific aspects of the data may be more meaningfully displayed in a graphical format.

Examples of some analyses are shown in Figures 3.4-1 through 3.4-3.

3.4.3 Statistical Procedures

Statistical procedures will be specific for each vegetation parameter to be monitored. Most analysis, however, will use the SPSS package for ANOVA, Analysis of Covariance, Fisher LSD, regressions, and other statistical tests. A description of the statistical tests to be used, the critical values, variables to be used and hypotheses to be tested are discussed below.

White River Shale Monitoring
Native Plants, Inc.

Litter Fall

Investigators_____ Date_____

Species_____ Location_____

Weight (gm)	Weight (gm)
1	16
2	17
3	18
4	19
5	20
6	21
7	22
8	23
9	24
10	25
11	26
12	27
13	28
14	29
15	30
$\bar{X}$	
s.d.	

FIGURE 3.3-1: Example Data Sampling Form for Litter Fall Measurements

White River Shale Monitoring/Native Plants, Inc.
Biomass Production of Annual Vegetation

Investigators_____ Date_____
Vegetation type_____ Location_____

	% Cover	Weight of clipped materials (g)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
$\bar{x}$		
s.d.		

FIGURE 3.3-2: Example Sampling Form for Biomass Production of Annual Vegetation.

White River Shale Monitoring/Native Plants, Inc.

Sagebrush Leader Growth

Investigators_____ Date_____

Location_____ Transect No._____

Leader Length (CM)	PLANTS																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20																				
$\bar{x}$																				
s.d.																				

FIGURE 3.3-3 Example Sampling Form for Sagebrush Leader Growth Measurements.

Native Plants, Inc./White River Shale

Browse Field Form

Location_____ Date_____

Transect_____ Observer_____

Vegetation type_____ Key species_____

Plant No.	Leader Length (mm)										$\bar{X}$	Form Class	Age Class	Leader Use
	1	2	3	4	5	6	7	8	9	10				
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														
19														
20														
21														
22														
23														
24														
25														
Average														

Form Classes

1. All available, no hedging
2. All available, lightly to moderately hedged
3. All available, severely hedged
4. Partly available, no hedging
5. Partly available, lightly to mod. hedged
6. Partly available, severely hedged
7. Unavailable
8. Dead

Age Classes

S - Seedling, 3 mm diam.
Y - Young, 3 mm - 13 mm diam.
M - Mature, + 3 mm diam.
D - Dacadent, 25% or more dead

FIGURE 3.3-4: Example Sampling Form for Browse Plant Utilization.

White River Shale Monitoring Project

Native Plants, Inc.

Lichen Monitoring

Study Area_____ Observers_____

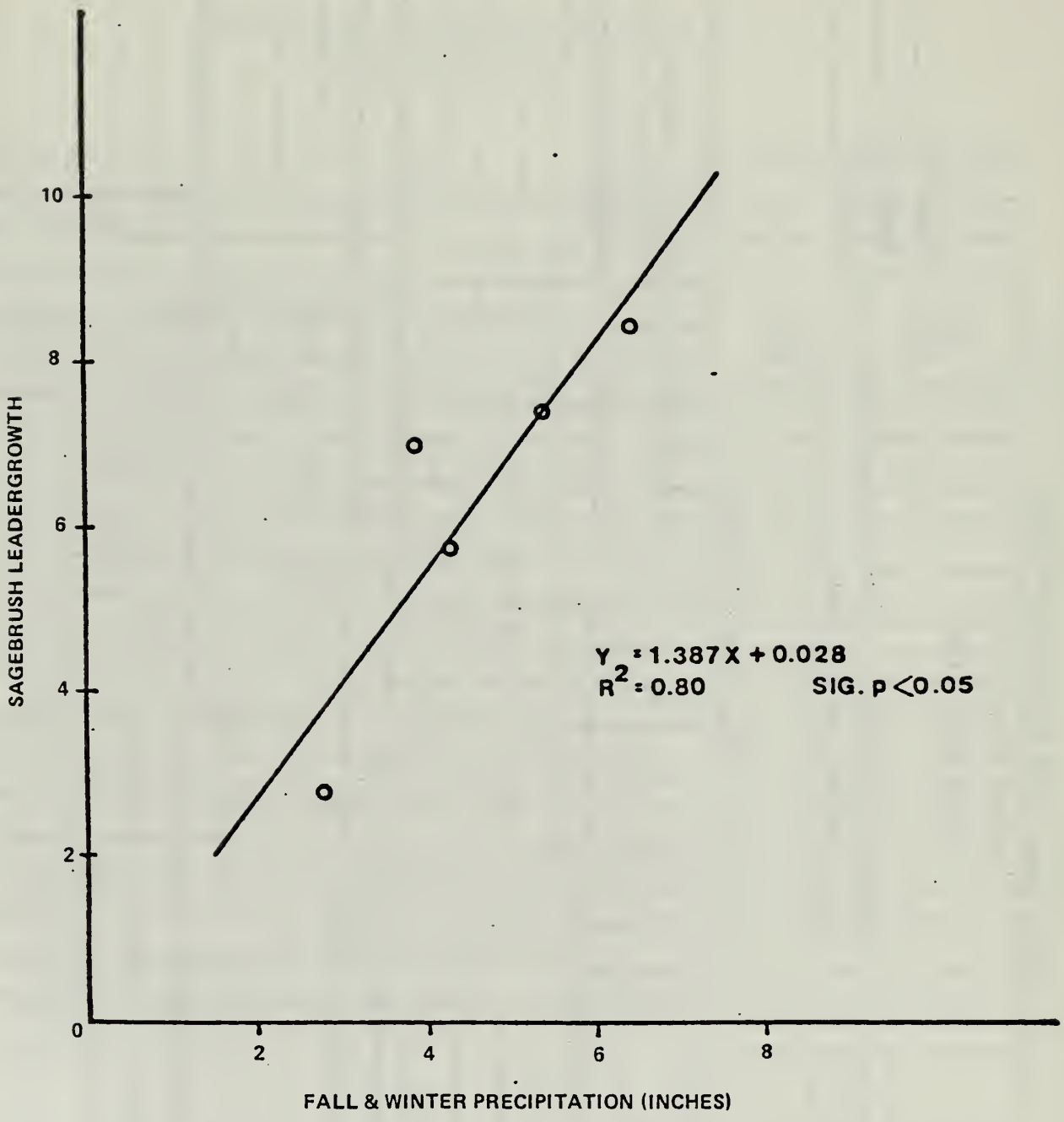
Transect No._____ Transect Direction_____ Date_____

Plot Location_____ Direction for starting Point_____ Workers_____

2cm x 50cm Quadrats

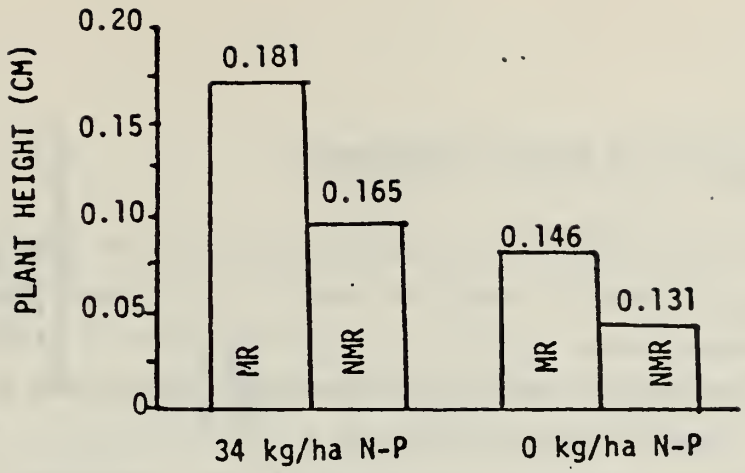
Species Cover Estimates	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Percent
Mosses																					
Lichens																					
Total Cover Estimates																					
Total Vascular Plant																					
Saxicolons lichens																					
Terricolous lichens																					
Mosses																					
Rock																					
Bareground																					

FIGURE 3.3-5: Example Sampling Form for Lichen Monitoring Measurements.



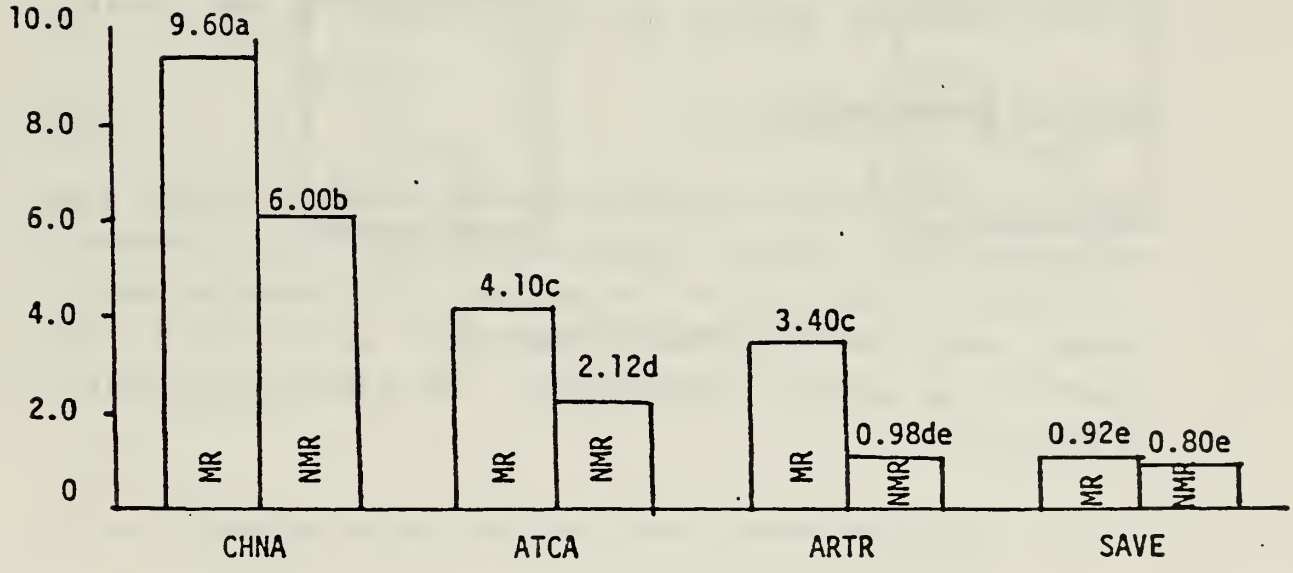
REGRESSION OF ANNUAL SAGEBRUSH STEM GROWTH
ON FALL AND WINTER PRECIPITATION

FIGURE 3.4-1



MEAN INCREASE IN PLANT HEIGHT AFTER A THREE-MONTH GROWING PERIOD IN THE GREENHOUSE FOR FOUR SHRUBS (ARTR, ATCA, CHNA AND SAVE): SHOWING INTERACTIONS BETWEEN INOCULATION AND FERTILIZER TREATMENTS

FIGURE 3.4-2



MEAN INCREASE IN PLANT HEIGHT AFTER A THREE-MONTH GROWING PERIOD IN THE GREENHOUSE FOR FOUR SHRUBS (ARTR, ATCA, CHNA AND SAVE): SHOWING INTERACTIONS BETWEEN INOCULATION TREATMENTS AND INDIVIDUAL SPECIES

FIGURE 3.4-3

Biomass Production of Annual Vegetation

Data gathered each year will be summarized by site and vegetation type. Comparisons will then be made to test if differences exist between sites or between years. Analysis of Variance (ANOVA) will be used to measure differences; if differences do exist, Fisher's LSD will be used to identify those differences (Figure 3.4-4 and 3.4-5). Other environmental factors such as rainfall will be correlated with annual biomass to determine as relationships.

The hypotheses under investigation are:

H_0: Biomass production of annual vegetation is unchanged between sites (or years).

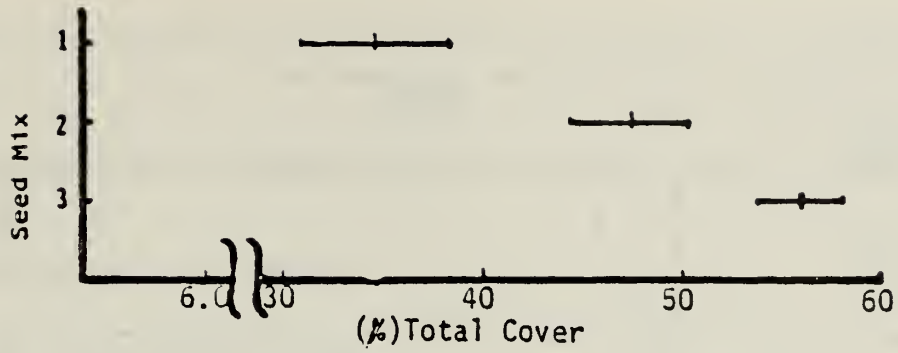
An Analysis of Covariance test that will adjust for inherent variability of the data will be applied to test this hypothesis. Annual biomass will be used as the dependent variable, pre-and post-operation as the independent variable, and spring rainfall as the covariate.

Sagebrush Leader Growth

Several hypothesis will be tested concerning differences between sites and between years. These will be tested using ANOVA and if differences are detected, Fisher's LSD will be applied. Also, regression analysis between abiotic factors (precipitation, etc.) and sagebrush leader growth will be performed (Figure 3.4-6). The principle hypothesis to be tested is:

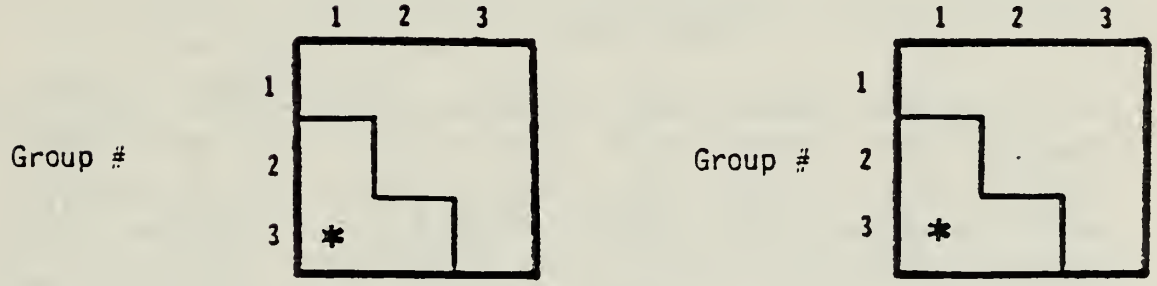
H_0: Sagebrush leader growth has not changed between sites (or years).

Again, this hypothesis will be tested by obtaining data from each site and comparing the baseline data gathered prior to develoment with the new data from the monitoring program.



USING STUDENT-NEWMAN-KEUL PROCEDURE

FIGURE 3.4-4



USING SCHEFFE PROCEDURE

FIGURE 3.4-5

PAIRWISE COMPARISONS

Years		Sites 1	2	3	4
1976	X	3	2	1	2
	Y	10	8	8	11
1977	X	4	3	3	5
	Y	12	12	10	13
1978	X	1	2	3	1
	Y	6	5	8	7

X - sagebrush leader growth
Y - rainfall (cm)

ANOCOV Table

	df	SSx	SP	SSy	df	$SS\hat{y}$	$MS\hat{y}$	F
Years	2	9.50	20.75	55.17	2	17.49	8.75	6.20
Error	9	7.50	6.25	16.50	8	11.29	1.41	
Total		17.00	27.00	71.67		28.78		

ANALYSIS OF COVARIANCE, SAMPLE DATA

FIGURE 3.4-6

An Analysis of Covariance test will again be used because of inherent variability in the data. The dependent variable will be sagebrush leader growth with pre- and post-operation as one variable and rainfall as the covariate. The hypothesis will be tested at the 5% level.

Soil Microbiology and Soil Chemistry

The hypotheses to be tested will be:

H_0: There is no difference in the bacterial populations in the soil.

H_0: There is no difference in the fungal populations in the soil.

H_0: There is no difference in the activity of the enzyme dehydrogenase in the soil.

H_0: There is no difference in the respiratory activity of organisms within the soil.

In addition, moisture content, pH, EC and organic matter will be correlated to total bacteria, total fungi and microbial activity. These correlations will be compared to the relationships defined in the baseline program. This process of continued comparison may indicate the existence of gradual trends in the data.

The statistical analysis will include the calculation of means and standard deviations for:

- Total bacteria and fungi/gram of dry soil
- Dehydrogenase and respiratory activities/gram of dry soil
- Soil moisture content.
- pH
- Organic matter

These statistics will be calculated for each sample date, each transect, and sample depth.

Correlation analyses will be conducted that may show the relationship of the independent variables, total bacteria, total fungi and total bacteria and fungi to the independent variables dehydrogenase activity and respiratory activities. Similar analyses will also be conducted to show the relationship of total bacteria, total fungi, and total bacteria plus fungi (dependent variables) with physical and chemical soil parameters (independent variables). Microbial activities (dehydrogenase and respiratory activity) will also be correlated to several of the measured physical and chemical soil parameters. The correlation coefficients will be considered significant at the 5% level.

Lichen Growth

Two hypotheses will be tested in this task. They are:

H_0: Lichen populations measured by lichen cover or species richness has not changed through time.

H_0: Lichen tissue analyses has shown no significant differences in composition through time.

The first hypothesis will be tested using the permanent plots in which cover and frequency are measured. Paired t-tests will be used on these data comparing baseline values with operational monitoring data. Elements that are considered important in testing the second hypothesis are sulfur, fluorine, and aluminum. All tests will be conducted at the 5% significance level.

In addition, lichen cover and elemental concentrations (dependent variables) will be correlated to distance from the processing facilities (independent variable). More exact measurements of concentrations will

be determined by the air monitoring group after the processing plant becomes operational. These data will be correlated directly with lichen cover and elemental concentrations of post-operational sampling dates. All tests will be conducted at the 5% level of significance.

Litter Fall

Several hypothesis will be tested for these parameters:

H_0: Litter fall will not vary from site to site.
H_0: Litter fall will not vary from year to year.

The hypothesis will be tested by ANOVA and if differences are detected, Fisher's LSD test will be applied to detect which means are significantly different. Also, correlation and regression analysis will be applied to determine plant size and litter fall relationships and precipitation and litter fall relationships.

Plant Condition and Stress

Although much of the analysis will be of a qualitative nature, statistical approaches will be used. For example, areas receiving low and high effluent levels will be stratified according to vegetation type and randomly sampled within the monitoring areas. The null hypothesis under investigation is:

H_0: There are no differences in plant condition between years (or sites).

This hypothesis will be tested by paired t-tests, or an Analysis of Variance at the 10% level of significance. Selection of this critical

level makes it more likely to detect problems early and to initiate more detailed investigations that may be required than when smaller critical values (e.g., .05 or .01) are used.

Plant Utilization

The null hypotheses to be tested is:

H_0: Plant utilization by wildlife and livestock has not changed over the years.

Because utilization of plants by wildlife is variable and possibly dependent upon rainfall amount for a given year an Analysis of Covariance will be used. As with the previous parameters, the hypothesis will be tested at the 5% level.

Other relationships will also be tested such as the effects of precipitation and plant species on plant utilization. These hypotheses will be tested by regression and correlation analysis. Also, differences between sites and between years will be tested using ANOVA and Fisher's LSD.

Plant Chemical Composition

Samples for this parameter will be obtained during the October sampling period. Plant materials will be those collected for sagebrush stem growth measurements. The hypotheses to be tested include:

H_0: There is no difference in plant chemical composition from site to site.

H_0: There is no difference in plant chemical composition from year to year.

The two hypotheses will be tested using ANOVA and Fisher's LSD at p = 0.05. Two statistical comparisons are possible to detect differences caused by oil shale operation. First is the comparison of chemical levels in sagebrush plants in the areas subject to the industrial airborne effluents and chemical levels in plants not subject to effluents. Analysis of variance procedures will be used to test the whole set of data. A second comparison will be made on plant chemical data collected before and after industrial development using an analysis of variance test.

3.5 Critical Values and Development of Contingency Plans

3.5.1 Critical Values

Establishment of critical values for vegetation-related parameters are difficult to make at this time because they relate to population responses rather than process limits. An exception to this is with concentrations of elements in plant tissues or soils. In the latter case, EPA Standards (OTA 1980) would be used for critical values.

With regard to population responses a statistical approach will be utilized. Rejection of a null hypothesis at the 5% level will serve as a critical value that may trigger increases in sampling effort or in contingency sampling. An 80% confidence limit around the population mean will be used to define the critical range for single measurements. Any values that fall outside this interval may trigger contingency sampling..

3.5.2 Contingency Measures

Upon exceeding a critical value, further analysis or sampling will be conducted. Parameters that exceed the critical values will be brought to the attention of the monitoring team for comparison with other

related parameters. In general, contingency sampling will consist of increased sampling frequency or implementation of contingency monitoring program defined in Section 3.1.

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4.0 AQUATIC BIOLOGY

During the summer of 1981, the aquatic biology program, which was discontinued during the interim monitoring period (1977-1980), was reinstituted. The initial baseline data collection effort (1974-1976) was descriptive in nature and employed a somewhat different design philosophy than the present program. For example, artificial substrates were used for periphyton sampling rather than natural substrate. For this reason, the goal of the 1981 aquatic biology data collection program was to describe the aquatic ecosystem occurring on or near Tracts Ua and Ub and to develop an effective long-term monitoring program based upon the interaction of the natural physical and biological environment.

Data analysis for the first half-year is complete and forms the basis of the program detailed within this section. Parameters selected for monitoring were chosen from those that are accepted in the literature as important and that have proven to be of value for system description and impact detection. Moreover, these parameters have been shown to be important during this study.

4.1 Program Design and Rationale

The purpose of this monitoring program is:

- To gather data which describes the aquatic ecosystem in sufficient detail to allow assessment of natural or project-related change.

- To organize data collection and analysis using a conceptual view of the ecosystem to determine the cause or pathway of these changes.

- To assess the effectiveness of mitigation and reclamation measures.

The scope and nature of this program will change following construction of the Utah White River Dam. The Oil Shale Office will be consulted concerning any needed changs in program design and will approve such changes before they are instituted.

4.1.1 Potential Impacts

Identification of Potential Impacts to the Aquatic Ecosystem

Project-related activites which may cause direct or indirect change to the aquatic ecosystem are:

- Construction activities by direct alteration of stream channels or introduction of silt by runoff.
- Leachate from processed or raw shale piles introduced through groundwater infiltration.
- Airborne emissions including dust.
- Altered rates of organic and nutrient inputs from the terrestrial system.
- Reduced flow due to water withdrawal.

Direct effects upon aquatic vertebrates and invertebrates through habitat alteration during construction and operation of the project will be small. Approximately one acre of riparian habitat will be used for construction of the well and pumping system. This should not affect aquatic populations adversely.

Indirect sources of project impacts may include salts, metals, and hydrocarbons leached from processed and raw shale; fugitive dust; and deposition of particulates and other compounds in process emissions. Many of the compounds contained in these pollutants exhibit toxic effects in high concentrations to fish and aquatic life stages of other animals. Sublethal levels of many of these compounds produce more subtle effects than massive kills, such as altering egg and juvenile survival, disrupting chemical communication signals, and creating changes in morphological and physiological processes.

Direct impacts resulting from the project facilities are not expected to occur in structure or function of the White River during construction of the oil shale project. The project could cause functional changes in the aquatic ecosystem from disturbances during the operational phase of the project. These disturbances may include altered nutrients and organic and toxic compounds.

Alteration of rates of nutrient cycling and primary production by bacteria, fungi, and algae, coupled with altered patterns of organic input from the terrestrial system, can affect the amount and composition of food available to the higher organisms, invertebrates and fish. This can affect the population's species at higher trophic levels.

4.1.2 Parameters to be Studied

Physical, chemical, and biological parameters are to be measured in the aquatic program. In some cases (i.e., water quality), there is overlap between parameters measured in this program and under other programs. These overlapping parameters are site-specific and data concerning them must be collected at the same time as the biological data. The parameters to be measured in this program may be separated into operational, potential, and contingency parameters (Table 4.1-1).

TABLE 4.1-1

OPERATIONAL, POTENTIAL AND CONTINGENCY PARAMETERS
WHICH WILL BE MEASURED IN THE AQUATIC BIOLOGY
RESOURCES OF THE WHITE RIVER

Parameter	Operational	Potential	Contingency
Abiotic	DO, NH_3, NO_2, NO_3, total nitrogen, total phosphorus, PO_4-P, total suspended solids, pH	interstitial sediments, discharge, stream cross section profiles, silt load, turbidity	heavy metals, trace elements, micronutrients
	light intensity, dominant substrate, water velocity, temperature, conductivity		
Biotic	periphyton - species richness - species biomass - community biomass - density - diversity	periphyton - production - respiration - P/R ratio	aquatic microbiology fish - distribution - relative densities
	macroinvertebrates - species richness - species biomass - community biomass - density - diversity	macroinvertebrates - production	heavy metals in periphyton, macroinvertebrates and fish
		drift - organic input - insect input	
		decomposers/ decomposition rate	

Operational Parameters - Abiotic

The following parameters will define the physical and chemical conditions which exist in the White River. These parameters are the external driving variables in the river.

Water Quality. The following water quality parameters will be measured each time biological samples are collected: O_2; NH_3; total nitrogen; total phosphorus; PO_4-P; total suspended solids, and pH.

Physical Parameters. The following physical parameters will be measured each time biological samples are collected: light intensity profile; dominant substrate types; water velocity, conductivity, and temperature.

These parameters were chosen because they:

- o are indicative of the conditions found in desert river systems, and
- o are the external driving factors impinging upon biotic structure and function.

Operational Parameters - Biotic

Periphyton, Invertebrate Structure. The following biological parameters are measured on the periphyton (primary producers) and invertebrates (secondary, tertiary producers): richness (based upon lowest practicable taxon); biomass; density, and diversity.

The population and distribution of primary, secondary and tertiary producers is important in monitoring stream ecosystems because these populations are involved in the production and transfer of food energy from organism to organism in the food chain. In addition, these parameters will be monitored because they:

- measure components that are essential to ecosystem health, and

- are necessary to define ecosystem biotic structure.

These populations of plants, herbivores and predatory insects also serve as the food base of the fish populations in the White River. Thus, monitoring of these populations may indicate the trend in fish populations as well.

Potential Parameters - Abiotic

Physical Parameters. The following physical parameters are being investigated as potential monitoring parameters: interstitial sediment composition; discharge; stream cross section profiles; silt load, and turbidity.

The physical structure of the riverbed will be characterized by measuring the cross section and depth of the channel. The velocity of the water passing the cross section will also be measured so that flow characteristics can be determined and related to the water quality parameters discussed previously. In addition, the substrate (particle) size will be investigated to determine if the streambed (substrate) has changed. These parameters, particularly cross sectional area and substrate will be measured because they:

- have been shown to influence the load transported by a river;

- indicate the river's physical structure in terms of available habitat to primary producers and invertebrates (i.e. pools, riffles, runs);

- influence biological diversity, and

- o indicate substrate stability, an important aspect in terms of benthic biota and the ability to maintain "holdfasts" that resist scour or molar action of water.

Potential Parameters - Biotic

Periphyton, Invertebrate Production. Productivity estimates, defined here as production rate (P), respiration rate (R), P/R ratio, and change in biomass over time (net production) are indicative of the rate at which the plant and invertebrate populations are changing. These parameters will be measured because:

- o they are directly related to energy flow;
- o they are sensitive to abiotic change and therefore excellent pollution indicators, and
- o community level parameters (P), (R), and P/R, are easily measured.

Drift. Downstream drift, which consists of organic matter brought into an area of interest by flow from upstream areas, will be measured during the monitoring program. This study will measure the species composition and biomass of the invertebrate fauna, detritus, and other organic constituents.

These parameters will be measured because they:

- o are an important source of food to higher trophic levels, and
- o are important in defining the stream ecosystem.

Decomposers/Decomposition Rate. The determination of the rates and efficiencies of processing of organic material in the White River will be of primary importance. This is because present state of knowledge concerning the structure and function of stream ecosystems centers around the use of terrestrial organic matter by stream invertebrates. The following parameters will be measured: rate of organic decomposition, metabolic rate of organic decomposition, carbon and nitrogen content of decomposing organic matter. These parameters are important because of:

- o the dependence of consumer organisms for a majority of their energy supply on organic material from the terrestrial system (allochthonous production);
- o the utilization of this organic input during the fall-winter period prior to spring runoff;
- o the interrelationship between this allochthonous input and primary production (autochthonous), and
- o the importance of decomposition rate as an indicator of abiotic factors (Osborn 1980).

Contingency Parameters - Abiotic

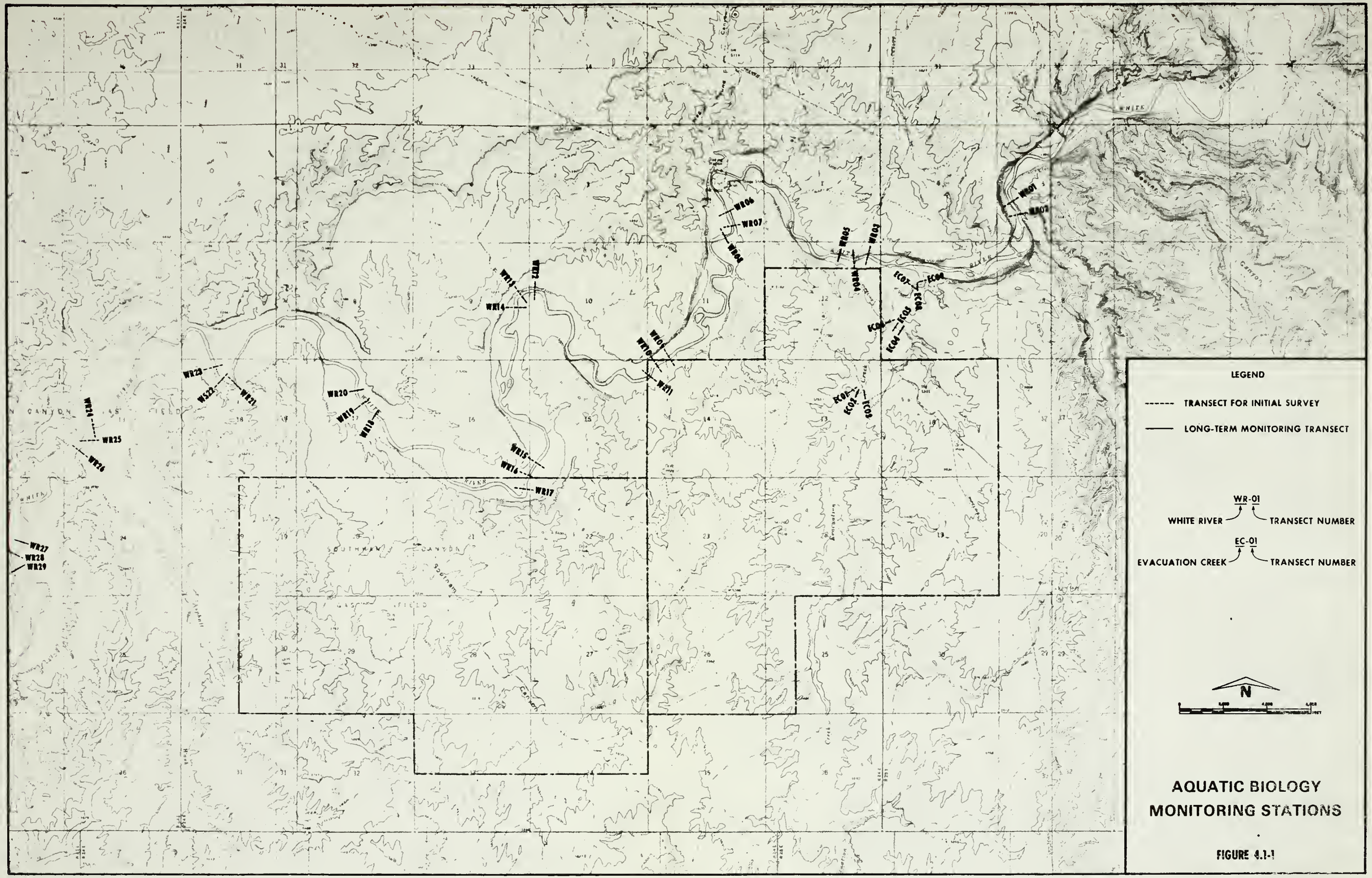
The abiotic parameters which will be measured as part of the contingency plan include: heavy metals in the ambient environment; micronutrients; and trace elements. Some of these parameters are already included in the water resources program (Table 6.1-3). If necessary these parameters will be measured at the locations and times biological and physical data are collected.

Contingency Parameters - Biotic

The biotic parameters which will be measured as part of the contingency plan include: heavy metal determinations in fish, periphyton and macroinvertebrates; aquatic microbiology, and fish. These parameters have been measured by WROSC personnel during 1981 and an extensive baseline study on the fish populations was recently completed. It is felt that if potential adverse project impacts are detected on lower trophic levels, investigations of the possible effects on the fish population will be documented. This will allow an integrated, comprehensive program of documenting impacts on the river ecosystem.

4.1.3 Sample Locations

The sample site locations on the White River and Evacuation Creek are shown on Figure 4.1-1. In order to determine the monitoring locations, data was collected on 29 transects (taken in groups of three, spaced two miles apart) on the White River. Physical parameters included detailed depth-velocity profiles, gradient, light penetration, substrate size, interstitial sediment and chlorophyll a. Data was summarized using cluster-analysis to determine the number of habitat types represented by the 29 transects. The analysis indicated two general types of habitats (Figure 4.1-2). Based on this investigation, each habitat type was selected from the transects upstream of the tracts, adjacent to the tracts, and downstream of the tracts. These transects are: upstream - transects 3 and 5; adjacent - transects 18 and 20; downstream - transects 27 and 29. Each pair of transects represents the two habitat types determined by cluster analysis. Transect 5, which was chosen as a pool/run type transect actually clustered with riffle type transects in the analysis. It was chosen based on subsequent field investigations which revealed it to be the nearest in character to a pool type which also was located upstream of the tracts and was accessible.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GAS FIELD
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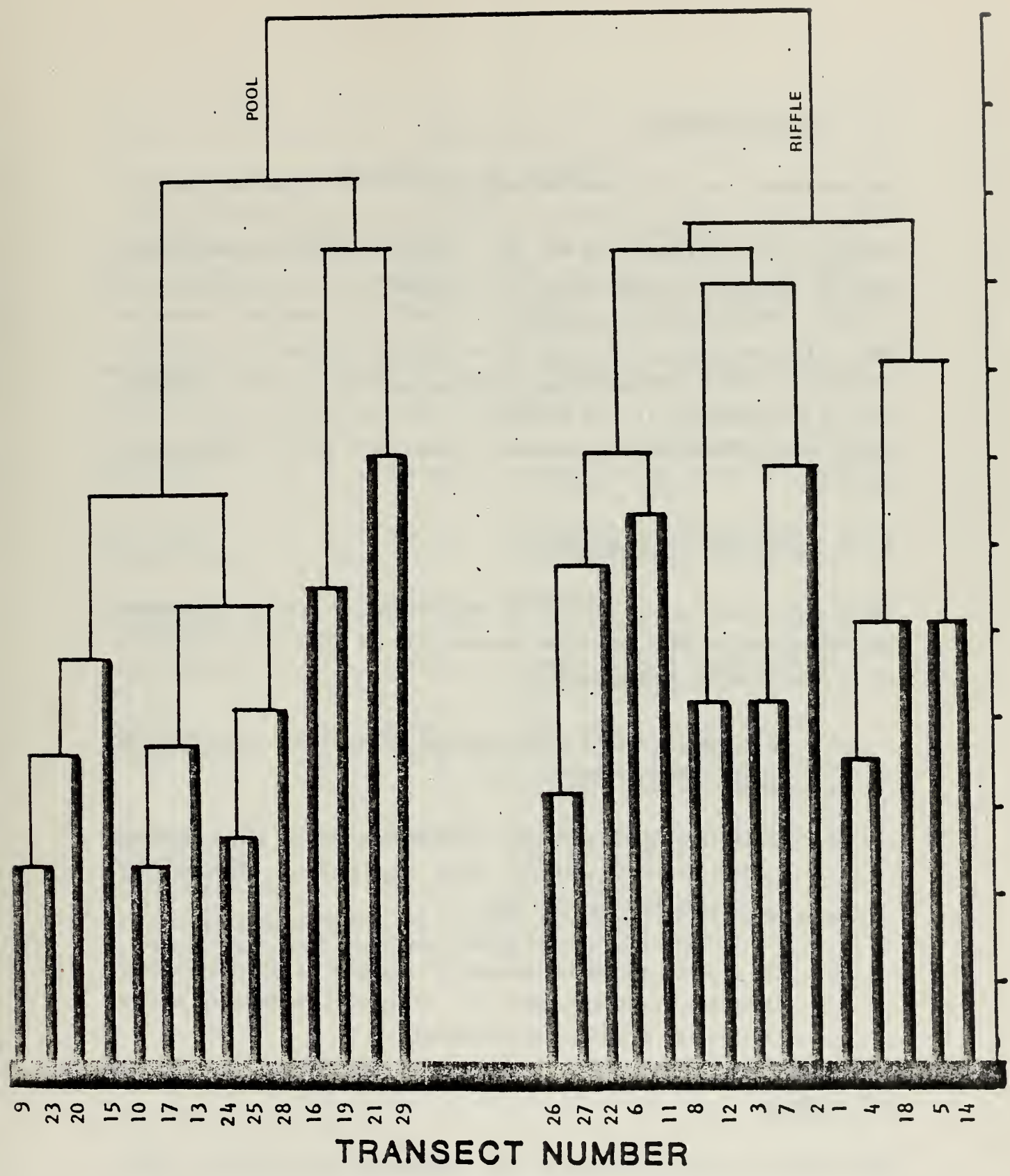
CANYON
LEGEND
TRANSECT FOR INITIAL SURVEY
LONG-TERM MONITORING TRANSECT
WR-01
WHITE RIVER
TRANSECT NUMBER
EC-01
EVACUATION CREEK
TRANSECT NUMBER
N
AQUATIC BIOLOGY
MONITORING STATIONS
FIGURE 4.1-1



A CLUSTER ANALYSIS PERFORMED ON THE 29 TRANSECTS
BETWEEN MILE 0 (HELL'S HOLE) AND MILE 17 (ASPHALT WASH) ON THE WHITE RIVER

FIGURE 4.1-2

4.1.4 Sampling Schedule

The parameters will be measured according to the schedule shown in Table 4.1-2. Those indicated as monthly will be measured at the intensive site (transects 18 and 20). These monthly measurements are made to augment existing data, build ecosystem relationships, and validate the usefulness of potential parameters. Quarterly measurements will be made at all three sites and provide the data base for control-treatment comparisons needed for impact identification. Monthly measurements will not be taken during peak runoff or anchor ice conditions. Therefore, approximately eight field visits will be made annually.

4.1.5 Fulfillment of Objectives

The stated objectives of documenting the pathway of foreign substances and determining aquatic ecosystem impacts will be fulfilled as a result of conducting this program because:

- parameters, sample locations and timing will describe the existing environment;
- parameters and locations selected are based upon expected project impacts, pathways, legal requirements, measurability and cost-effectiveness, and
- the aquatic monitoring program is designed to provide quality assurance, data management and analytical methods to ensure reliability of data interpretation.

4.2 Methods

Field data will be collected at the frequencies prescribed in Table 4.1-2. A minimum of five samples will be collected at each station and

TABLE 4.1-2

PARAMETERS TO BE STUDIED(1)

Study	# Sites	Frequency	Parameters
Water Quality	1 3	Monthly Quarterly	NH_3, NO_2, NO_3, Total-N, Phosphorus (total), Ortho-P, turbidity, total suspended solids, pH, DO
Periphyton Structure	1 3	Monthly Quarterly	Taxonomic composition, Chl a,b,c, phaeo-pigments/unit area, biomass (Chl a)
Invertebrate Structure	1 3	Monthly Quarterly	Abundance, biomass, taxonomic composition and diversity, associated CPOM, FPOM
Periphyton Productivity	1	Monthly	Production (P), Respiration (R), P/R, P/Biomass
Invertebrate Productivity	1	Monthly	Production
Invertebrate Drift	1	Monthly	Biomass, taxonomic composition, associated CPOM, FPOM
Channel Geomorphology	1 3	Monthly Quarterly	Cross section, substrate and interstitial sediment size distribution, depth, velocity, light intensity profile, temperature
Decomposers/ Decomposition	1	Monthly	Detrital decomposition rate, C,N, C/N, respiration

(1) Quarterly measurements are taken at upstream (control) transects and at near-tract and downstream transects (treatments).

shall represent the major habitats in proportion to their occurrence. As the variability in each parameter is better understood, sample size will be adjusted to increase the effectiveness of the monitoring parameters. See Section 4.4, Aquatic Resources Data Analysis for a discussion of sample size. As with all aspects of the WRSOC monitoring program, all changes will involve approval by the Oil Shale Office.

The following methods will be used in sample collection.

Water Quality Parameters

Water quality parameters to be studied in this monitoring program should include those noted in Table 4.1-1. Chemical analyses will be conducted as described in EPA (1979).

Population

Periphyton Structure

The primary producers in the aquatic environment will be sampled using methods derived by Squires et al. (1973) and Petcairn and Hawkes (1973). This task involves the removal in a quantitative manner, of periphytic species from natural rock surfaces on the creek bottom. Samples will be analyzed for species type, abundance and density. In addition, chlorophyll a, b, c and pigments/unit area will be measured. Measurements of biomass will be determined as mg chlorophyll/m^2. A preserved reference collection of taxonomic groups of periphyton will be maintained.

Invertebrate Structure

Quantitative samples will be taken with a modified Hess sampler (0.250 mm nitex mesh, 1380 cm^2 area) to a depth of 10 cm. Samples will be sugar floated (Anderson 1959). The samples will be washed, sieved

through a #35 U.S. standard sieve, and preserved in 70% ethanol (Stnd. Mthds. for Examination of Water and Wastewater, APHA, AWAA, WPCF, 1975).

Samples will be hand-picked in pyrex pans over a light table under a 2X illuminated magnifier, enumerated by taxa (family), and length determined for productivity by measurements. Reference specimens will be stored in separate vials in case comparison with future samples or verifications are desired. Identifications will be made under a Bausch and Lomb stereo zoom dissecting scope. Keys to be utilized in identification include Edmunds et al 1976, Merrit and Cummings 1978, Usinger 1971, and Wiggins 1977.

Invertebrate drift patterns will be determined during each sample period at a single sample site by taking six samples during a 24-hour period. The upstream organic contribution to the study site will be determined by dry-weight of organic matter per m^3/sec.

Primary, Secondary and Community Productivity and Decomposition

Biomass will be determined by numbers and known relationships between organism size and weight. Productivity estimates will be done using the techniques described by Osborn 1980; Hamilton 1969, and Hynes 1968.

The biomass of detritus (CPOM) collected concurrently with the macroinvertebrate samples will be determined by drying the remaining material not collected by picking, at 105°C for 48 hours, and weighed to the nearest 0.0001 grams.

At a single sample station, ecosystem level in-situ production and respiration studies will be conducted. Continuous monitoring of light, temperature and oxygen during the sample period will be undertaken. The following parameters will be calculated from this data:

1. Gross/net production
2. Production/respiration
3. Production/periphyton biomass
4. Production/Chl a, b, c
5. Community respiration

Primary production will be measured by removing natural substrate from the river and placing it in the photosynthesis and respiration chambers, while community respiration will be measured with intact substrate.

A comparison between the decomposition rates due to microbes and the contribution of decomposition due to macroinvertebrates will also be studied at this location. Pre-leached ambient organic material (primarily cottonwood leaves) will be placed in screened enclosures which are anchored in the river. Fine mesh and coarse mesh enclosures will be used to exclude invertebrates for a direct measure of microbial decomposition. These enclosures will be sampled monthly to measure respiration (using P/R chambers), biomass as dry weight to obtain percent loss through time and percent nitrogen.

Substrate

Substrate samples are collected from stream bottoms to determine the substrate size distribution and the amount of organic material. The samples are dried at 105°C and weighed by size fractions as follows:

>12.7 mm
> 4.0 mm
> 0.5 mm
> 0.25 mm
< 0.25 mm (silt)

The organic content of the smallest sieve size fraction is determined by weight loss on ignition by burning at 600°C for 20 minutes.

Stream Cross Sections (Depth and Velocity)/Channel Geomorphology

For each cross section, a depth/velocity profile will be constructed. At each location, determine elevation and water depth to the nearest 1.0 cm. At alternate points, determine water velocities at the bottom and at 10 cm depth intervals, including the surface as the final point (Cochrauer 1976, Silvey 1976, Collings 1972, World Meterological Organization 1970).

Light

The attentuation of total irradiance from direct and indirect insolation within the White River Stream System will be measured with an underwater photometer employing a 1 cm^2 silicon photovoltaic cell. These photocells respond to light of wavelengths between approximately 300-750 nm (Wetzel and Likens 1979, Strickland 1958, Souberer 1962, Westlake 1965). The physical structure of the instrument is a hemispherical design (Rich and Wetzel 1969).

4.2.1 List of Materials

The following list of materials are needed for the aquatic study of the White River.

1. Surveyors' level and tripod
2. Stadia rod
3. post driver
4. sledge hammer
5. flagging tape
6. fluorescent paint
7. Aluminum clipboards
8. velocity meter with two sets spare batteries
9. light sensor, stand and meter
10. clear plexiglas tube samplers
11. snorkel and mask
12. Eckman dredge
13. blue tube sampler
14. Hess sampler
15. drift nets - clamps, hammer, screwdriver
16. tool kit

14. Hess sampler
15. drift nets - clamps, hammer, screwdriver
16. tool kit
17. 4-foot and 5-foot steel rods for drift nets
18. P/R chambers
19. spare pumps
20. electrical cable - 50-foot grounded (4)
21. multiplug outlets
22. three oxygen meters with probes - extra batteries
23. one conductivity meter - extra batteries
24. YSI telethermometer, 50-foot cable
25. Turner III fluorimeter
26. three coolers, one small cooler
27. chlorophyll bottles (36)
28. ziploc bags
29. whirlpac bags
30. periphyton bottles
31. three toothbrushes
32. three small pen knives
33. acetone - 9 liters @ 250 ml/sample
34. formalin - 2 liters
35. stereo zoom dissecting microscopes
36. triocular phase microscope with camera
37. B&L model 70 spectrophotometer
38. pH meter
39. top-loading and analytical balance
40. magnetic stirrers (2)
41. homogenizer
42. glassware, chemicals
43. portable generator
44. portable heater
45. lugols' - 100 ml
46. wash bottles
47. boat, motor
48. life jackets
49. waders
50. wet suit, dry suit, gloves and hood
51. ice auger

4.3 Quality Assurance/Quality Control Procedures

The overall objective of the quality assurance, quality control program developed for the aquatic biology program will be to provide data that are complete, accurate, precise, and reliable. This program is designed to allow a comparison of data and results drawn from the

data regardless of personnel used. The precision and accuracy checks on the raw data will permit adequate defense of the data and the conclusions to be drawn (Figure 4.3-1).

Methods approved and established by the U.S. EPA Monitoring Program are used. All data will be recorded accurately on permanent report forms (examples provided). Along with these data, all quality assurance and control activities will be documented and filed.

4.3.1 Quality Assurance Program Design

Sample Collection, Preservation and Transportation

All procedures for collection, preservation and transportation of chemical, microbiological and biological samples are as outlined in EPA (1979) and APHA (1980).

Sample bottles are made of the materials specified in the above references and are specially cleaned at the laboratory according to their intended use. If preservation is necessary, the preservative is added at the time the sample bottles are cleaned. A water-proof label is attached which specifies the parameter(s) for subsequent analysis, the preservative added, the field number, date, time of day, sample site name and location, and collector.

The processes of sample collection in the field are exactly as specified in the references. After proper collection in the field, the collector fills out all information on the label of the bottle. The sample is iced in a cooler and transported to the lab as soon as possible.

Data for parameters which do not allow transport back to the lab (flow, temperature, depth, etc.) are recorded in the field notebook. These data are later approved by the lab supervisor and stored with the

laboratory's permanent analytical records. Figure 4.3-1 outlines the quality control program detailed below.

Chain of Custody Procedures and Sample Handling

Samples collected in the field are kept secure at all times by the person who collected the sample. This includes maintenance of proper light and temperature conditions during transportation.

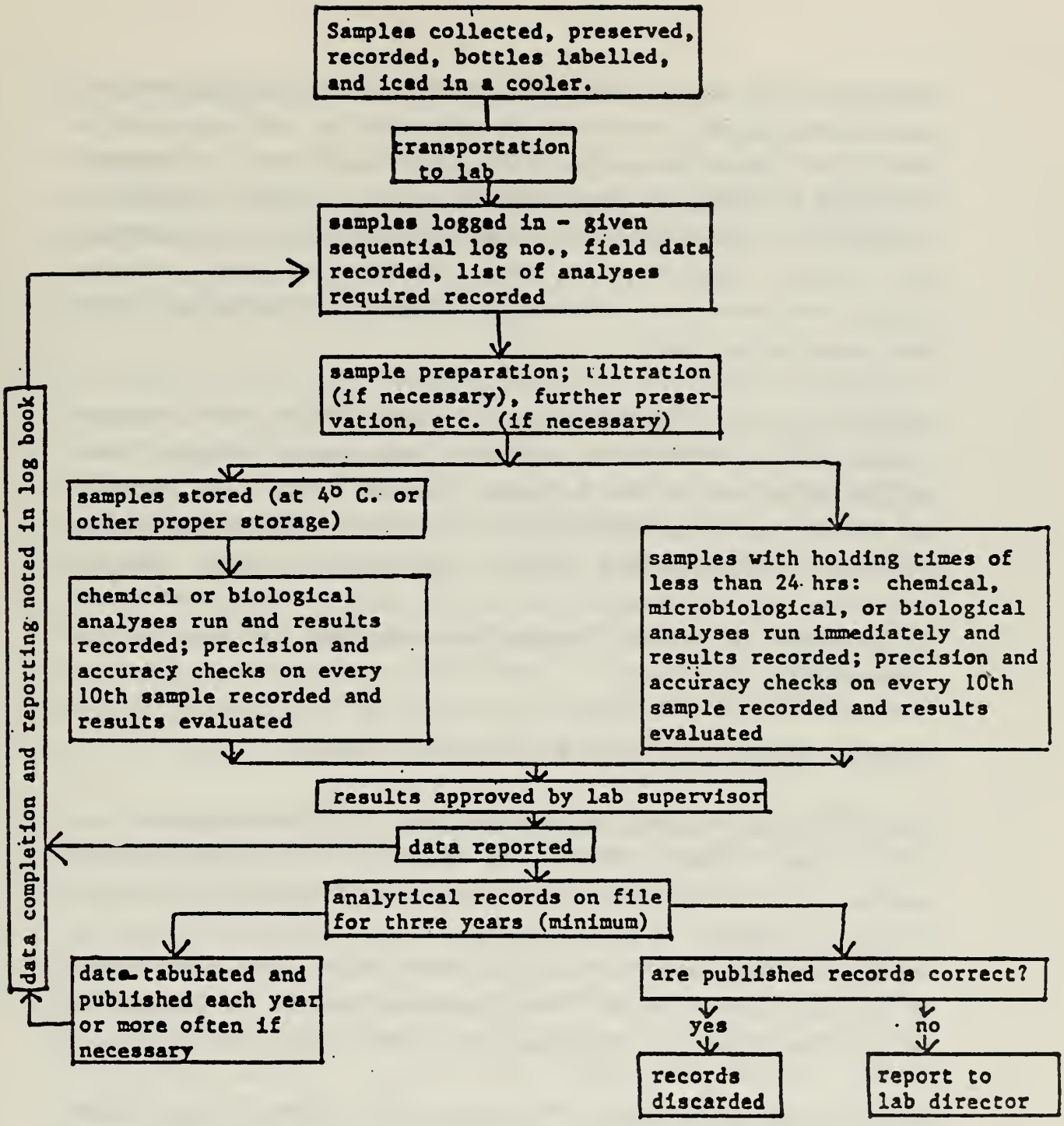
When the samples arrive at the lab, they are logged in and identified using a permanent log book. Each log entry shows the sequential log number given to the sample, date and time collected, date received at the lab, sample site name and location, analyses required, date of data completion and the date when the data are reported.

Further sample preparation (such as filtering, further preservation, etc.) is then carried out. Samples with specified holding times of less than 24 hours are analyzed at this time. Samples which require storage are stored at 4°C or as specified according to the reference manuals and analyzed within the designated holding times.

Completed analytical and quality assurance results are reviewed and signed by the lab supervisor before progress or final reports are submitted. Raw data and copies of reports are kept on file for a minimum of three years.

Precision and Accuracy Files

Data on the precision (reproducibility) and accuracy (the difference between observed and known values) are generated and filed on a yearly basis for each parameter studied. Samples used for precision and accuracy studies are chosen in an unbiased manner and cover the entire applicable concentration range expected for each analysis. For studies documenting precision, a minimum of seven replicate determinations are



AN INFORMATION FLOW DIAGRAM WHICH INDICATES THE MAJOR STEPS IN THE QUALITY ASSURANCE/QUALITY CONTROL PROGRAM FOR THE AQUATIC PROGRAM ON THE WHITE RIVER

FIGURE 4.3-1

performed on the samples chosen. The results are handled statistically and relative standard deviations (%) calculated for each concentration level. For studies documenting accuracy, the same samples are "spiked" with known quantities of pure standard chemical reagent. The concentrations of a minimum of seven replicated spiked samples are determined and a percent recovery of the spike calculated for each. Relative standard deviations are calculated for the percent recoveries within each concentration level.

These precision and accuracy data are kept on permanent file and reviewed yearly, when a new method is incorporated, or when a new analyst begins work on the designated parameter. All daily replicate and spiking data (discussed below) are compared to the compiled yearly statements. Results which vary by more than ± 2 relative standard deviations from the mean are the warning level. Results which vary by more than ± 3 relative standard deviation from the mean are not acceptable.

Reagents, Standards and Daily Quality Control Checks

Analytical grade reagents and standards from reliable sources are used at all times. The quality of the reagents are checked each time samples are analyzed. Values for blanks and standards and standard curves are generated with each analytical run. Duplicate and spiking analyses are also completed daily on every tenth sample. Evaluation of the duplicate and spiked results determine whether the analysis is being correctly run and in agreement with common lab practices.

Corrective action is taken, if necessary, to bring the analysis back in conformance with previous test results. Final approval of all results, whether chemical, microbiological or biological, is the responsibility of the lab supervisor.

Preventive Maintenance of Laboratory Instruments

Instruments for chemical, microbiological and biological determinations are calibrated with each use. Maintenance and cleaning are performed as needed and as outlined according to the manufactor's instructions.

Internal Quality Control Sample Checks

On a quarterly basis for chemical parameters and certain biological parameters, each technician analyzes internal quality control samples (knowns) which have been prepared by the lab supervisor. These samples and their "true" values are provided by the EPA Monitoring and Support Laboratory. Results must fall within acceptable limits as defined by the lab's yearly precision and accuracy records, discussed above.

For microbiological parameters, each technician incorporates positive and negative controls on a daily basis. The positive control is a check on the quality of the culture media prepared. The negative control is a check on the sterile technique used.

For biological parameters (such as identification and counting of invertebrates) the lab supervisor will perform quarterly quality control checks on the capabilities of the technicians.

On a quarterly basis or at the beginning and end of extended intensive surveys, the lab supervisor will also provide blind audit samples to the technicians. These samples will be given fictitious identifications and the audit will consist of two samples: one "unspiked" sample and one "spiked" sample covering the concentration range of applicable parameters.

Results for the samples must fall within the lab's accumulated precision and accuracy limits.

All internal quality control records and subsequent evaluations will be kept on permanent file.

Proficiency Testing (External Quality Control)

On a yearly basis, the proficiency of the lab is evaluated by the State of Utah, Division of Heath. Chemical, microbiological and biological samples for all requested parameters are delivered by the State Quality Assurance coordinator. The lab analyzes these samples and reports the results to the State for evaluation. The overall results of the proficiency testing are available to all parties contracting work through the lab.

Yearly evaluation is also required by the EPA to complete laboratory certification. Audit samples are mailed from the EPA to particpating labs in cooperation with the State of Utah Quality Assurance Coordinator. The notification concerning proficiency results and subsequent lab certification is handled through the State Quality Assurance Coordinator.

4.3.2 Example Quality Control/Quality Assurance Documents

A set of sample documents following the prescribed quality control, quality assurance program used in the aquatic program can be seen in Appendix 4A.

4.4 Aquatic Resources - Data Analysis

4.4.1 Data Management

Computer software and data management for the project are designed to ensure consistency and accuracy. Quality of data received from field personnel will be maintained by: (1) using coding forms designed to minimize data recording errors; (2) syntactic data verification to

maximize recognition of data errors, and (3) command structures for standard analyses to minimize errors in data handling and processing.

Field coding forms are designed with several concerns in mind: (1) ease of use for field personnel; (2) ease of data entry to the computer, and (3) complete identification of each line of data. These attributes minimize errors created during data acquisition.

Data files are proofed by various programs which check for syntactic errors in the data. Various fields in the file are checked against a list of valid codes or the codes found are tabulated for a manual check. Where possible, alphabetic codes are preferred to numeric codes to enhance detection (recognition) of errors. Redundant fields of data (as in data, location fields) are duplicated automatically in contiguous blocks to prevent loss of integrity of sample units by data entry errors.

Command structures have been developed which supervise the entry verification and processing of standard categories of data. This ensures that specific instructions to utility programs (such as duplication and sorting programs) are not mistyped.

Short-term storage of data is on-line with long-term storage on magnetic tapes (as well as backup mag tape storage of on-line data). Raw data files are stored in their original format to maintain readability by the field personnel who are ultimately interested in their integrity.

Each of the following categories of data has been developed in the above fashion: Physical habitat survey, sediment classification, sediment organic content, chlorophyll (a, b, c), periphyton biomass, invertebrates, drift, production/respiration, decomposition and water chemistries. Each category is processed in a similar fashion using many of the same utility programs as well as unique programs.

4.4.2 Establishment of Aquatic Ecosystem Relationships

The function of the data collection described in Section 4.1 is two-fold. First, it is used to establish relationships which describe important aspects of the aquatic ecosystem before mining impacts have occurred. Second, once project operations begin, the data is used to measure the impact of these activities on the ecosystem.

Descriptions of the aquatic ecosystem before the project begins are generally of two types; single parameter measures and relationships between two or more parameters. An example of a single parameter might be the density of aquatic insects in August in mile 70 of the White River, while the dependence of photosynthesis on light intensity is an example of a relationship between two parameters (photosynthesis levels and light levels).

A variety of statistical techniques are used in establishing these descriptions of the aquatic ecosystem of the White River. Single parameters are typically described as a mean with a confidence interval about this mean. These parameters collected at different sites and times may be compared using appropriate statistical tests (e.g., tests of means, analysis of variance, cluster analysis) to investigate similarities and differences. Temporal and spatial relationships of similar parameters may be established in this way. For example, the biomass of insects in the drift may be the same every river mile on the White River but may change by month. Thus, a single parameter for insect density in the drift could be used for each month.

Significant relationships between parameters often show that there is a cause and effect relationship between two or more parameters. These relationships may be hypothesized as a result of accepted ecological theory, or results of previously collected data. Statistical techniques including simple and multiple regression, analysis of variance, cluster analysis, factor analysis, parametric and non-parametric tests

of means (e.g. pooled t-test, Mann-Whitney test), and others may be employed to test for and establish meaningful relationships. In the situation where statistical techniques such as correlation matrices are used to generate hypothesized relationships, further data collection is essential to establish the validity of the relationship. These methods are used to establish the existence of hypothesized relationships such as the dependence of photosynthetic activity on light intensity.

4.4.3 Program Output

The following is a list of output data which will be generated from field and laboratory studies. These will be used singly and where appropriate to first describe and then monitor the White River ecosystem.

- o Physical Habitat Survey - used to characterize substrate type, depth-velocity regime and channel morphology.
  - For each transect during each sample period:
    - (i) output date, transect number, time of day
    - (ii) output stream width, maximum depth, mean depth, mean velocity
    - (iii) output discharge (m^3/sec) from depth-velocity data
    - (iv) plot stream profile with:
      - each bottom point indicated with letter representing substrate class
      - velocity isolines
      - indicate water's edge and surface
      - indicate sample locations

- o Summarize the following parameters for each sample period and location with means, standard deviations for cross section. Note: a location is defined as an individual sample point, five of which compose a transect sample. Plot the mean cross section values for each sample period as a function of time.

- Percent sediment size fraction in each of five fractions
- Percent organic content in sediment silt size fraction
- Chlorophyll a, b, c, mg/m^2
- Periphyton numbers and biomass by order, genus
- Invertebrate numbers and biomass by order, family, genus and functional group

o Parameters not specific to a cross section.
- Drift - summarize by location, data, time:
  (i) mean, dry weight of organic matter gm/hr
  (ii) mean invertebrate numbers and biomass by order, family, genus and functional group
  (iii) plot diurnal drift for taxa and functional groups as a function of time of day
- Decomposition rate - summary by date:
  (i) mean and standard deviation of weight loss as a function of time (gms/30 days)
  (ii) mean and standard deviation of specific respiration rate (mg O_2/hr-gm leaf material)
  (iii) plot mean weight loss and specific respiration rate as a function of time of year
- Production/Respiration rates - summary by date:
  (i) maximum net production, mg O_2/mg chlorophyll-a
  (ii) maximum respiration, mg O_2/mg organic matter
  (iii) plot maximum net production, maximum respiration as a function of time of year

Statistical analysis and plotting routines follow the programs in DATAPLOT, MINITAB, RUMMAGE and SPSS. DATAPLOT is a program designed to produce finished pen and ink drawings of desired graphs. MINITAB, RUMMAGE and SPSS are a series of programs designed to perform statistical analysis of desired data sets from mean, standard deviation and simple correlation to multivariate statistics. This software is actively maintained and available as a vital component of the overall data analysis and management programs.

4.5 Monitoring Impacts and Development of Contingency Plans

4.5.1 Methods of Identifying Impacts (Critical Values)

Detecting environmental changes due to project-related activity involves detecting changes in parameters or relationships that describe the aquatic ecosystem. This is a two-step process. First, changes in parameter values or in the relationship between parameters must be observed. Then, once a change has been observed, the cause of the change must be documented.

Since the major goal of the monitoring program is to detect environmental changes, the statistical tests in these analyses will generally be conducted at the 10% level of significance. This means that even if no changes have occurred, one in ten estimates of a parameter will be calculated as being significantly different than the "normal" value. The reason for using the 10% significance level is to increase the probability of detecting a change due to an impact. The smaller the significance level of the statistical test, the less likely one is to detect changes due to an impact. In statistical terms, as one decreases the probability of a type I error (concluding there is a change in a parameter when there actually isn't one) the probability of a type II error (concluding there is no change in the parameter value when indeed there actually is a change) increases. The detection of impact-related changes is subject to type II errors.

Thus, while more erroneous conclusions about significant change in a parameter when none have occurred (type I error) will result with a significance level of .10 than with a significance level of .05 (as traditionally used), the probability of detecting mining-related changes will be increased (type II error decreased). The increased chance of a type I error is not a major problem because a significant difference between the current estimate of a parameter and its "normal" value only flags that parameter as possibly being different due to

project-related activities. Further investigations are then commenced to determine the cause of this change or to establish that no change has actually occurred (i.e., the "flagged" parameter estimate is due to normal variability).

The parameters measured in this monitoring program will allow the detection of project-related impacts as well as allow for the development of relationships to identify the source of such impacts. The detection of changes in parameter values or relationships is accomplished by testing the following general hypothesis:

H_o: There is no difference between the values of a parameter for the above-tract (control), on-tract (treatment), or below-tract (treatment) sites.

This hypothesis is tested by comparing mean values of a parameter from various sampling periods and sample locations. For example, consider the following two statistical tests.

H_o: There is no difference in monthly periphyton biomass levels (mg Chl $\underline{a}/m^2$) for the above-, on-, and below-transects at a $p = .10$ level.

The above hypothesis was tested using 1981 field data. Graphical evaluations interpretation (Figure 4.5-1) suggests that no differences are apparent for monthly mean values (N=5). A two-way analysis of variance (Table 4.5-1) indicates no significant difference by transect, but significant differences over time.

A second example of the test of this general hypothesis using macroinvertebrate mean monthly biomass (gms/m^2) level is given below.

H_o: There is no significant difference in monthly macroinvertebrate biomass (gms/m^2) for the above-, on- and below-transects of a $p = .10$ level.

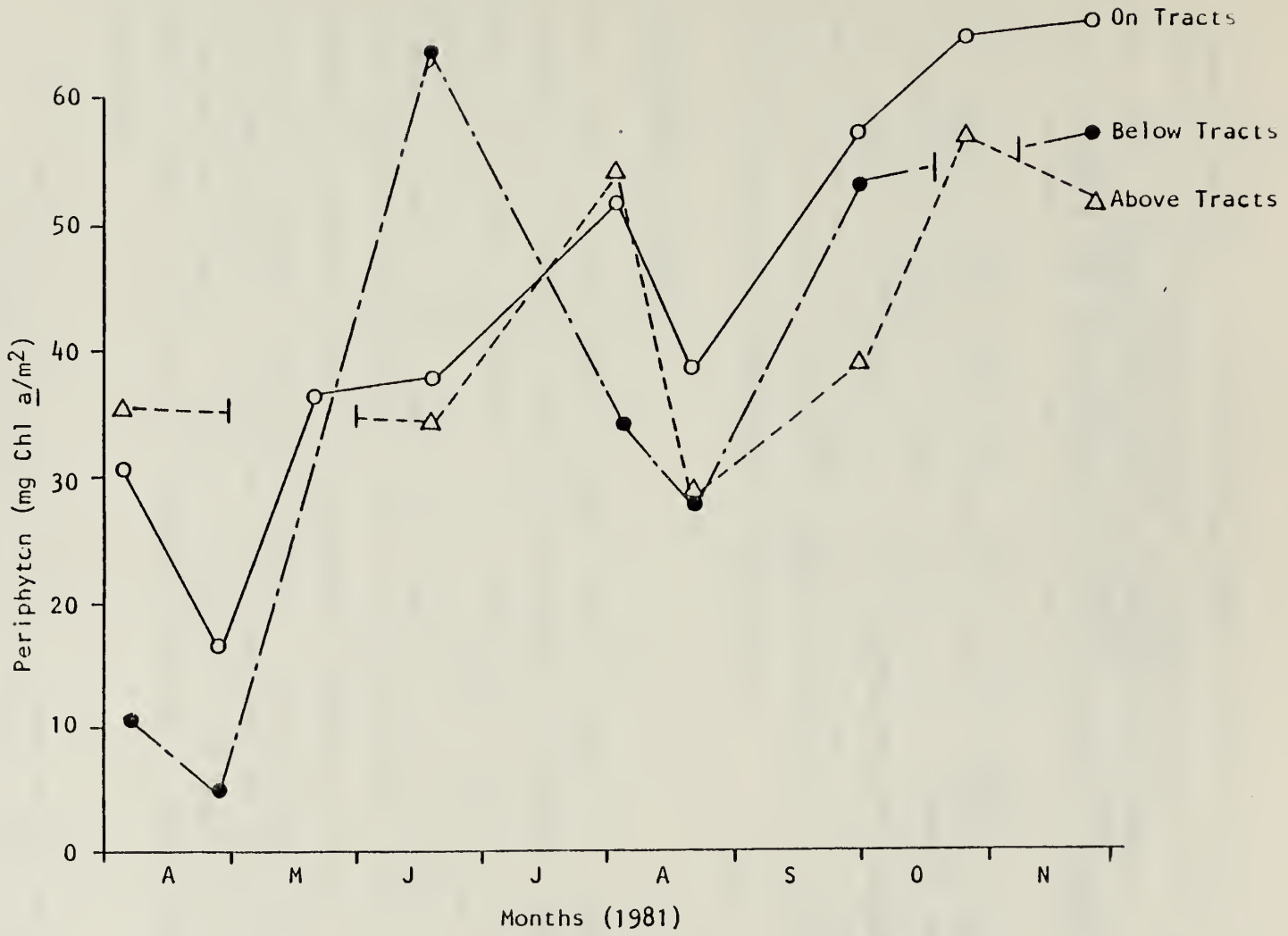


Figure 4.5-1. The monthly mean values (N=5) for periphyton biomass at the above, on-site, and below riffle transects on the White River, 1981. Standard errors are not given.

TABLE 4.5-1

A TWO-WAY ANALYSIS OF VARIANCE FOR TIME (MONTHLY AVERAGES; N=5) AND TRANSECT LOCATIONS (t_3 - ABOVE; t_{18} - ON-SITE; t_{27} - BELOW) FOR PERIPHYTON BIOMASS. PROBABILITY LEVELS (p) ARE GIVEN FOR EACH F-TEST

ANOVA	df	ss	ms	F	p
Block (transect)	2	2.3	1.1	1.02	0.361
Treatments (sample period)	9	42.9	4.8	4.35	0.000
Error	118	129.5	1.1		
Total	129				

Graphical analysis of the data (Figure 4.5-2) indicated that the annual pattern of macroinvertebrate biomass for the above- and on-site transects were similar; however, the below-site transect appeared to be different when compared to the two other transects. A two-way analysis of variance for all three transects indicated a significant difference ($p < .10$) between transects and time. However, a two-way analysis of variance including just the above- and on-site transects indicated no significant difference between transects, but a significant difference over time (Table 4.5-2). Thus, it has been demonstrated by baseline monitoring that the above- and on-site mean ($N = 5$) monthly values for periphyton and macroinvertebrate biomass were not significantly different but showed temporal differences.

Refinement of Program

The results stated above indicate that this analytical design is sensitive to detecting existing environmental differences. The next step is to determine whether this experimental design can detect project-related impacts. In order to determine this in the White River, a second set of transects (pool habitats) was also sampled. The environments, which presently exist in the White River, are heavily impacted by natural events. A hypothetical question (in order to test our ability to detect change) may be asked. "Can we detect a change in our normally stable (riffle) sites if we assume that the data collected from our pool transects represents an on-site riffle transect that has been perturbed by projected related activities?" A formal statement would be:

Ho: There is no significant difference between monthly mean ($N = 5$) periphyton biomass for the above-site riffle transect and the on-site riffle transect at a $p = .1$ level of significance.

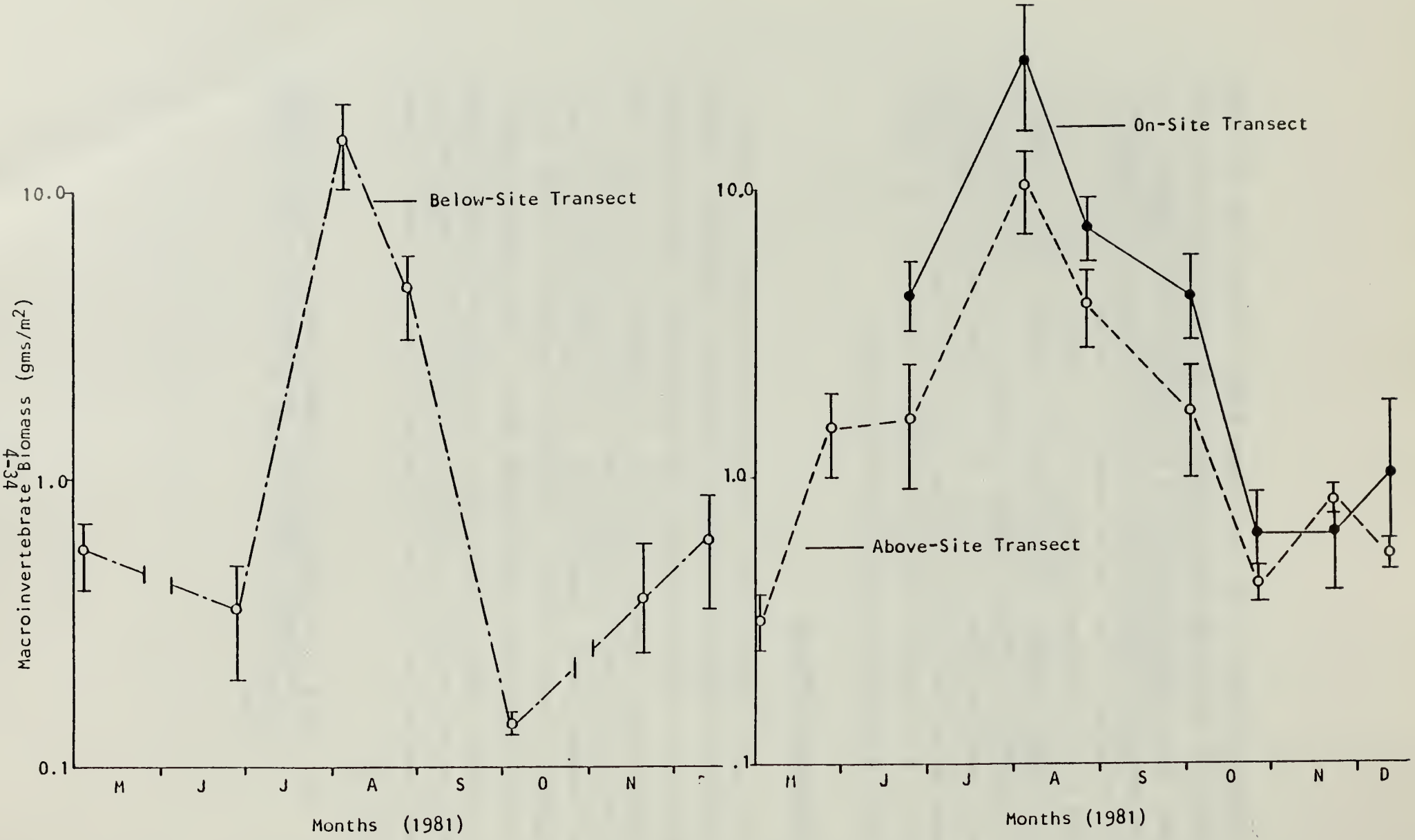


Figure 4.5-2. The monthly mean values (N=5) for macroinvertebrate biomass at the above, on-site, and below riffle transects on the White River, 1981. Standard errors are given for each transect.

TABLE 4.5-2

A TWO-WAY ANALYSIS OF VARIANCE FOR TIME (MONTHLY AVERAGES; N = 5) AND TRANSECT LOCATIONS (t3 - ABOVE; t18 - ON-SITE; t27 - BELOW) FOR MACROINVERTEBRATE BIOMASS. PROBABILITY LEVELS (P) ARE GIVEN FOR EACH F-TEST

ANOVA	df	ss	ms	F	P
Block (transect)	1	4.9	4.9	1.56	0.216
Treatments (sample period)	6	140.3	23.4	7.48	0.000
Error	62	193.7	3.1		
Total	69				

H_0: There is no significant difference between monthly mean (N = 5) macroinvertebrate biomasses for the above-site riffle transect and the on-site riffle transect at p = .10 level of significance.

Graphical presentation of the data for these two transects (which hypothetically represent the above- and on-site riffles) can be seen in Figure 4.5-3. A statistical comparison between these transects using a Mann-Whitney test can be seen in Table 4.5-3.

The results of this analysis indicate that if project-related impacts are within the same range of change found in naturally perturbed habitats in the White River, the present design will detect these changes. In the event the null hypothesis is rejected and a change is detected, analysis for the cause is undertaken. This analysis follows the logic and example described in Section 8.3, Impact Detection and Contingency Planning.

The aquatic program is in a dynamic state of flux. An attempt is being made to reduce sample variability and increase accuracy, precision, and sensitivity. For example, the experimental design of taking five samples across the stream has resulted in the introduction of a certain degree of variability in some parameters. Periphyton biomass (Figure 4.5-4) in the three riffle transects has been shown to be related to depth. In a similar manner, the distribution of many of the biological parameters have also been related to substrate size (Figures 8.2-6, 11). Using our present sample design, standard deviations for periphyton biomasses are 76.9% of the mean and for macroinvertebrates biomasses are 89.8% of the mean (Figure 4.5-5). Hence, sensitivity and accuracy may be increased reducing the variability in sample collections. For example, more intensive sampling within single substrate size would eliminate the habitat-related component of sample variability and perhaps make statistical analysis more definitive.

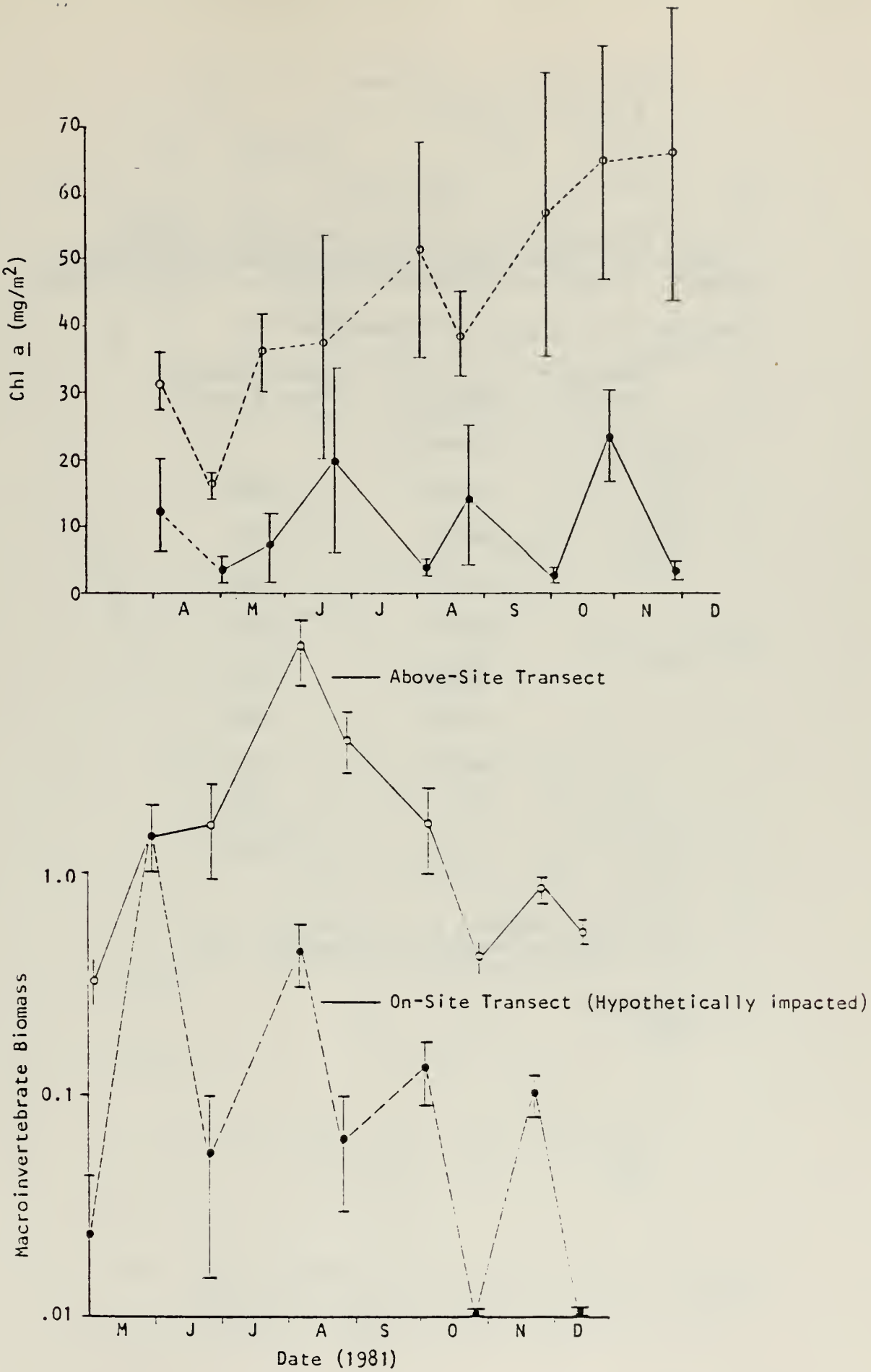


Figure 4.5-3. A comparison between mean monthly periphyton and macroinvertebrate biomass for a riffle transect (above site) and a pool transect (labeled on-site transect; hypothetically impacted). Data collected for both

TABLE 4.5-3

A COMPARISON OF SIGNIFICANT DIFFERENCES BY SAMPLE PERIOD (N = 5) FOR PERIPHYTON BIOMASS AND MACROINVERTEBRATE BIOMASS. SIGNIFICANT DIFFERENCES AT THE p = .1 LEVEL ARE GIVEN

p LEVEL FOR MANN-WHITNEY TEST

Sample Period	Log Chl a	Log Macroinvertebrate Biomass
0	.1745	--
1	.0216*	.1266
2	.0216*	1.0000
3	.4034	.0373*
4	.0216*	.0122*
5	.0513*	.0122*
6	.0122*	.0601*
7	.0601*	.0122*
8	.1437*	.0367*
9	.0947*	.0200*

* Significant at p = 0.10 level (p = .1 used for detecting differences in monitoring program).

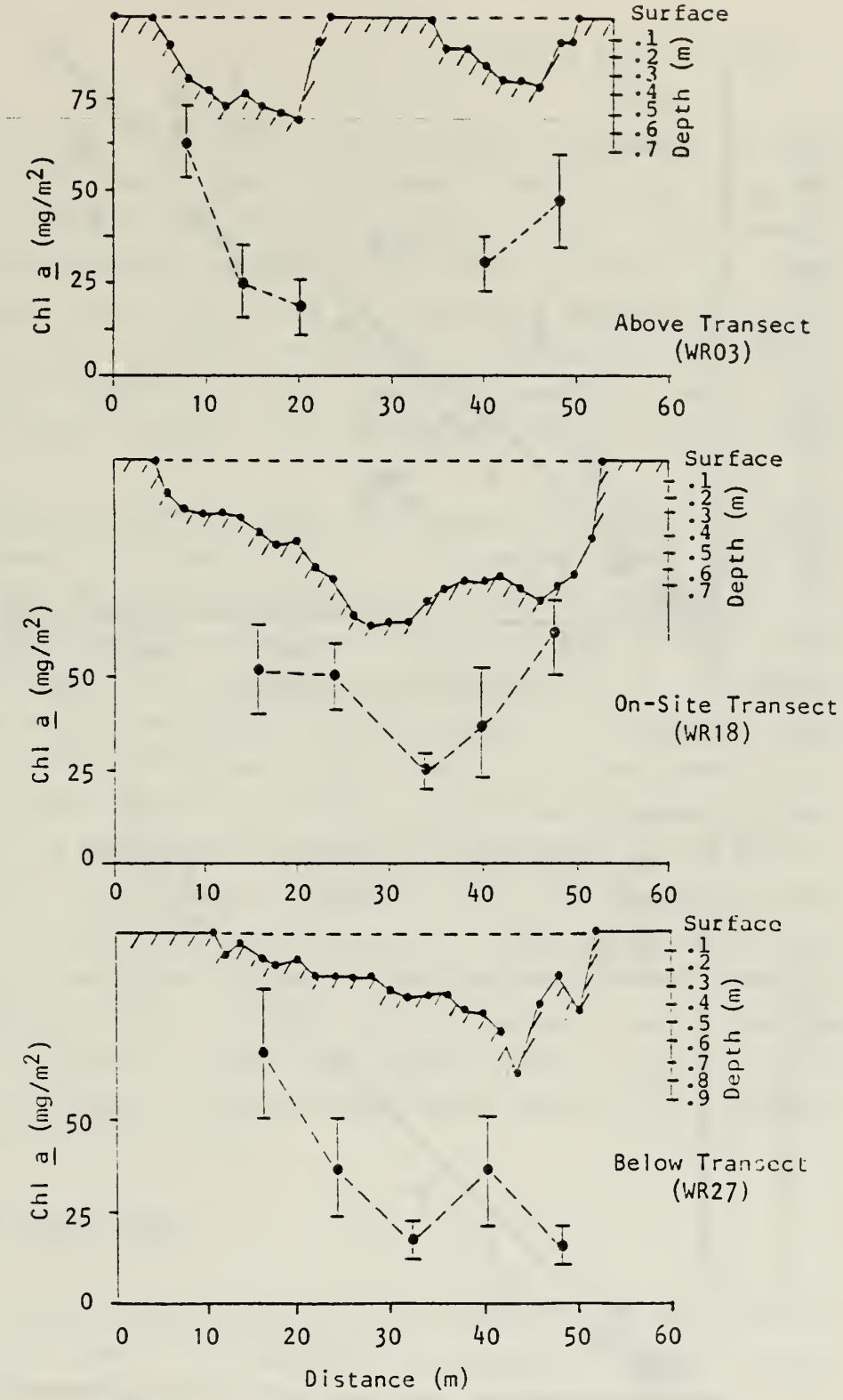
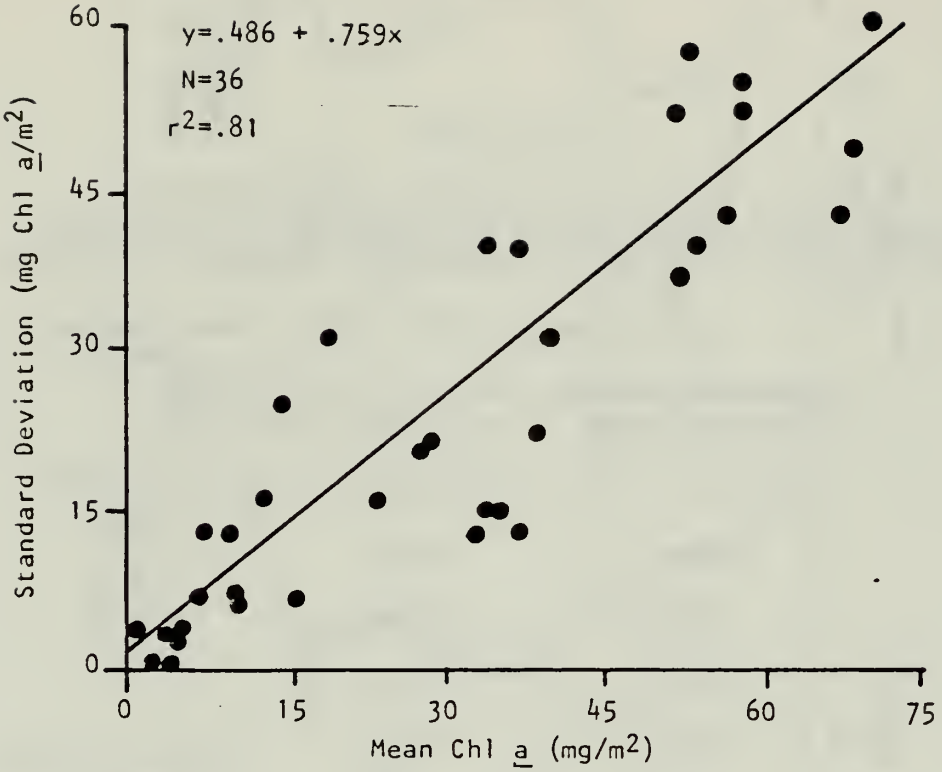


Figure 4.5-4. The distribution of annual mean (N=9) periphyton biomass estimates by distance across the stream for three riffle transects in the White River. Data collected in 1981. Standard errors are given.



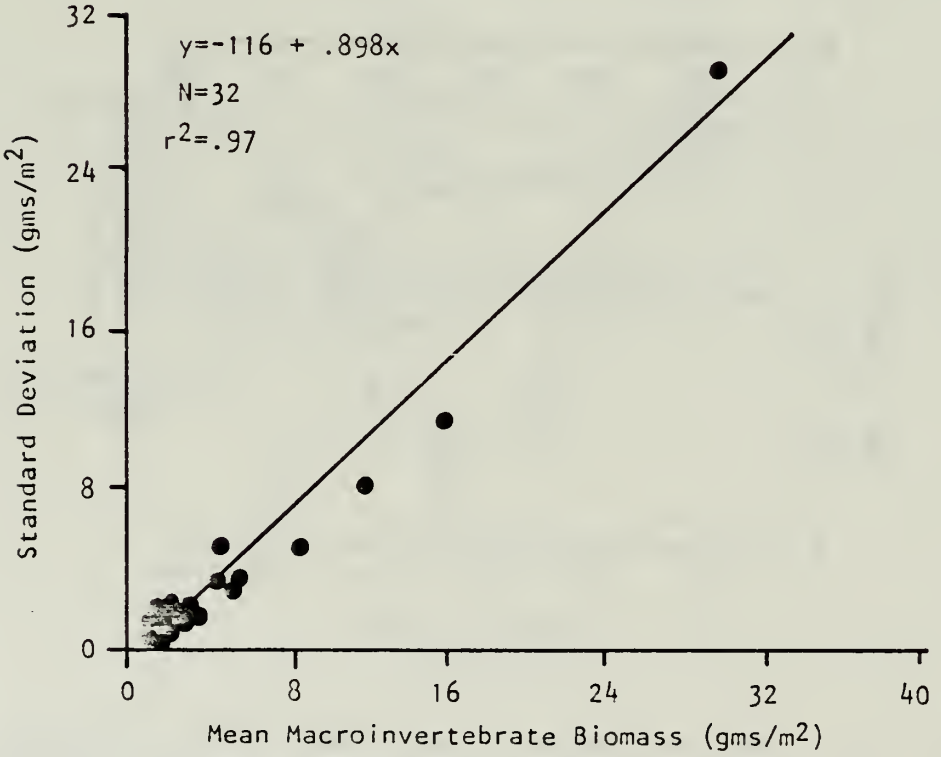


Figure 4.5-5. The relationships between biomass levels and the standard deviations for macroinvertebrate and periphyton biomass estimates in the White River, 1981.

In order to detect an impact (percent change compared to the above site) a certain sample size is required. The relationship between sample size needed to detect a certain percent change in the biomass of periphyton and macroinvertebrates can be seen in Figure 4.5-6. These data are based upon a two-tailed test using the existing variance at the above site. As stated previously, an attempt is being made to decrease the variability, and thus, reduce the sample size necessary to accurately detect a change (e.g., 50% change from the control site).

A second technique which is under development at this time is the use of relationships to detect impacts. For example, Osborn (1981) has indicated that the rate of decomposition of organic material in river systems may be critical to the structure and function of that system. These data confirm the results of Cummins (1979). A relationship between the rate of decomposition and degree days in the water has been developed for the White River (Figure 4.5-7). This relationship will be used to detect impacts by testing for significant changes (at the p = .1 level) in the rate of decomposition (the slope of the line in Figure 4.5-7). Also, because it appears to be a very important driving variable in the ecosystem, monitoring this relationship may help in attempting to determine changes in the macroinvertebrate community which cannot be directly related to natural causes or project-related impacts. An example of impact and pathway analysis using an aquatic ecosystem relationship (production/respiration versus light intensity) is presented in Section 8.3.2.

4.5.2 Contingency Plans

Using the rationale described above, the management program is able to use logic which leads to the appropriate contingency plan, mitigation, or change in reclamation in the event of an adverse effect, or no action in the event the state is normal. An integral component of the following procedure, the computer program "MONITOR," was developed to streamline the analytical process. This is explained in Section 8.4, Impact Detection and Pathway Identification Using "MONITOR."

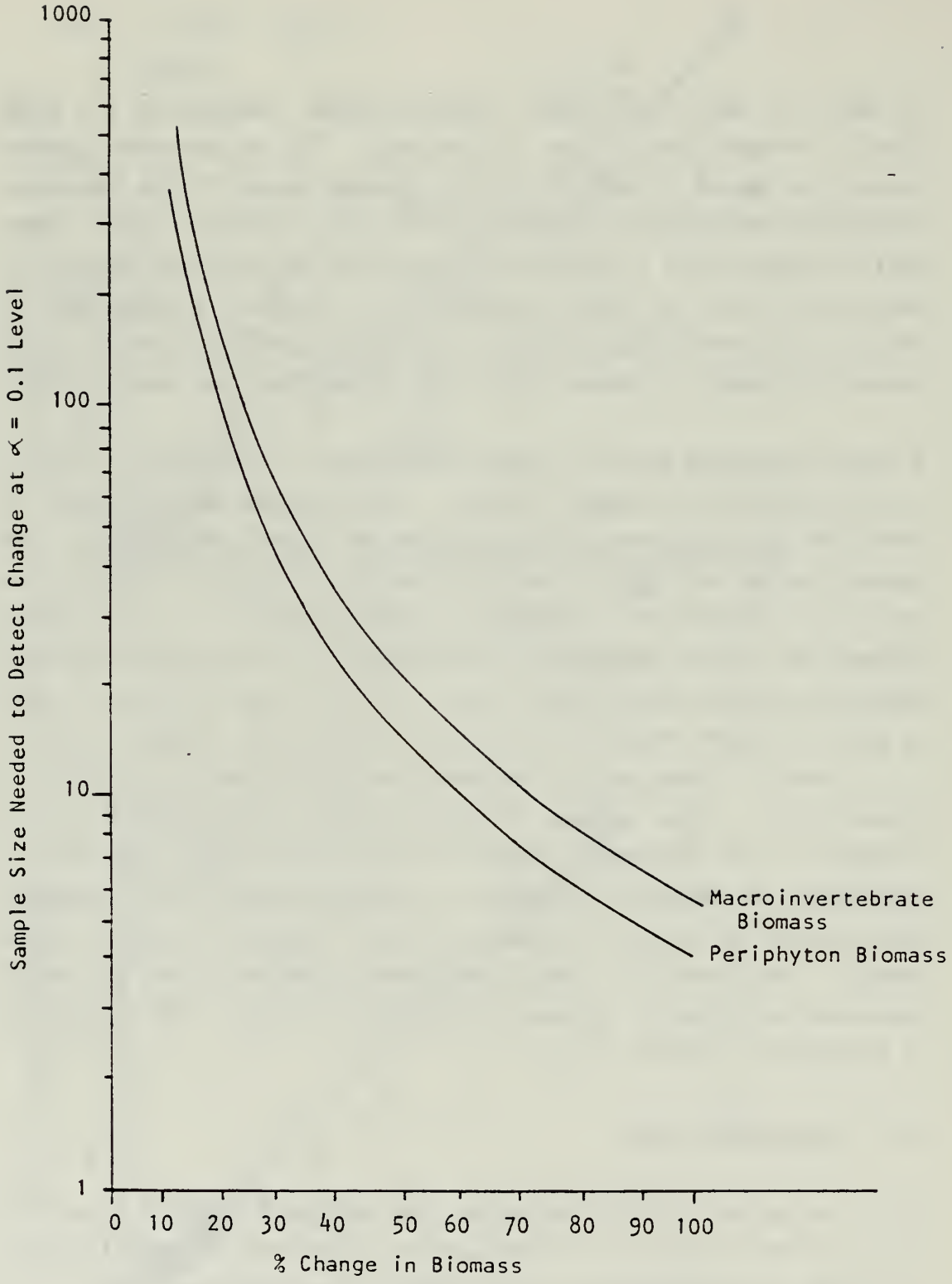


Figure 4.5-6 . The relationship between the sample size necessary to detect a given percent change in periphyton and macroinvertebrate biomass in the White River. These curves are based upon data collected in 1981 with the variance of the control site. A two-tailed test was used in this analysis.

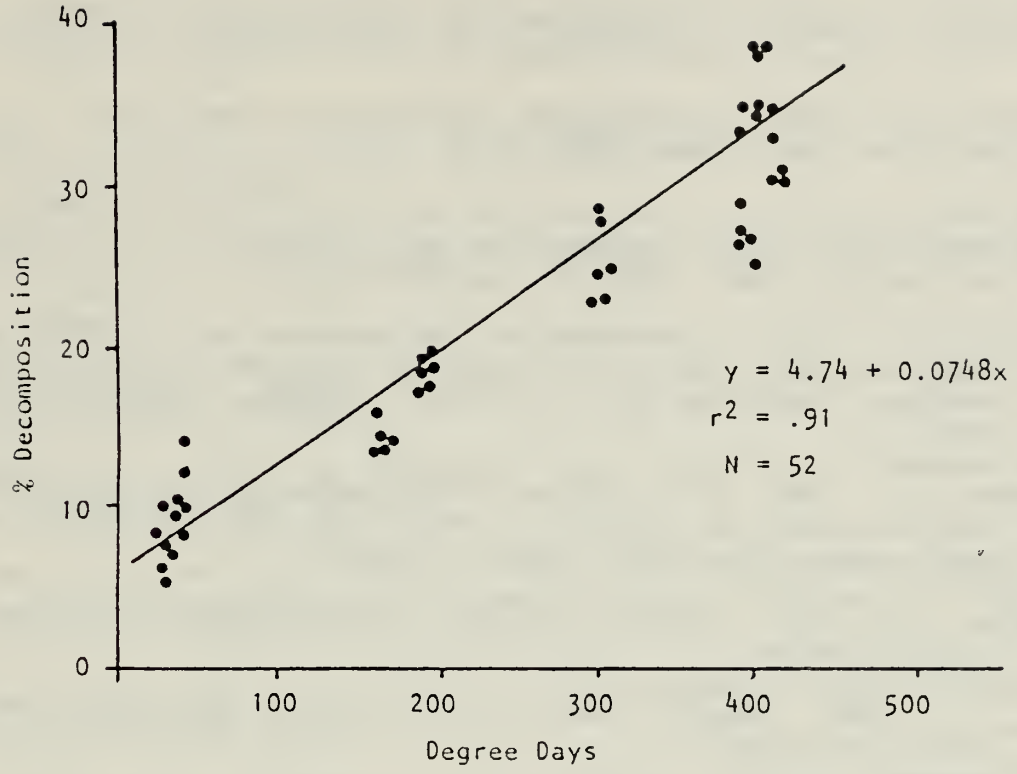


FIGURE 4.5-7 Leaf decomposition studies conducted in the White River (October, 1981 — April, 1982) at km 79

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APPENDIX 4A

QUALITY CONTROL

PRECISION AND ACCURACY TERMS AND CALCULATIONS

Note: Calculate the theoretical concentration of the spiked sample, TH-SP, in the appropriate units for the analysis in question. Use the terms and equations below for collecting precision and accuracy data.

UNSP = concentration of the unspiked sample in (ug or mg)/l, NTU, or umhos/cm; use the mean, $\overline{x}$, from precision data.

CONSP = concentration of the spiking solution in (ug or mg)/ml

M = mass of spiking compound in mg

QC = "true" value of the internal quality control in (ug or mg)/l, or NTU

S_1 = sample volume in liters.

S_2 = CONSP volume added in ml.

S_3 = sample volume plus CONSP volume in liters

EX-SP = experimentally determined concentration of the spiked sample in (ug or mg)/l or NTU

%D = percent deviation of the experimentally determined spiked sample from the theoretical concentration

$$= \left[\frac{(EX\text{-}SP) - (TH\text{-}SP)}{TH\text{-}SP}\right] \times 100$$

Note: Retain sign as positive or negative

%R = percent recovery of the spike

= 100 + %D

$\overline{\%R}$ = mean percent recovery

$$= \frac{\sum \%R_i}{N}$$

where:

N = the number of replicates

$\%R_i$ = the %R for each N

$\overline{x}$ = mean value for precision data

$$= \frac{\sum x_i}{N}$$

where:

N = the number of replicates

x_i = the x value for each N

s = standard deviation of the percent recovery or precision data

$$= \sqrt{\frac{\sum(\%R_i - \overline{\%R})^2}{N - 1}} \quad \text{or} \quad \sqrt{\frac{\sum (x_i - \overline{x})^2}{N - 1}}$$

R.S.D. = relative standard deviation of the percent recoveries or precision data, (%)

$$= \left(\frac{s}{\overline{\%R}}\right) \times 100 \quad \text{or} \quad \left(\frac{s}{\overline{x}}\right) \times 100$$

QUALITY CONTROL DATA; PRECISION

Parameter: _____ Date: _____

Method: _____ Analyst: _____

Reference: _____

Concentration (ug, mg)/l or _____

N	Sample # _____	Sample # _____	Sample # _____	Sample # _____
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
$\bar{x}$				
s				
R.S.D.				

Precision Statement:

Using water samples at concentrations of _____ (ug,mg)/l and _____ (ug, mg)/l _____, the standard deviations were ± _____ and ± _____ units, respectively. The relative standard deviations were _____ percent and _____percent, respectively.

QUALITY CONTROL DATA; ACCURACY

Parameter:_____ Method:_____

Peference:_____ Analyst:_____ Date:_____

	Sample #: _____ UNSP = _____(ug,mg)/l CONSP = _____(ug,mg)/ml TH-SP = _____(ug,mg)/l			Sample #: _____ UNSP = _____(ug,mg)/l CONSP = _____(ug,mg)/ml TH-SP = _____(ug,mg)/l			Sample #: _____ UNSP = _____(ug,mg)/l CONSP = _____(ug,mg)/ml TH-SP = _____(ug,mg)/l			Sample #: _____ UNSP = _____(ug,mg)/l CONSP = _____(ug,mg)/ml TH-SP = _____(ug,mg)/l		
N	EX-SP	%D	%R	EX-SP	%D	%R	EX-SP	%D	%R	EX-SP	%D	%R
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
$\overline{\%R}$												
s												
R.S.D.												

S_1 = _____ S_2 = _____ S_3 = _____

Accuracy Statement:

Using water samples at concentrations of _____(ug,mg)/l and _____(ug,mg)/l _____, the recoveries were _____% and _____% respectively. The standard deviations for percent recoveries were ± _____ and ± _____ units, respectively. The relative standard deviations were _____% and _____%m respectively.

QUALITY CONTROL DATA; ACCURACY

Parameter: _____ Method: _____

Reference: _____ Analyst: _____ Date: _____

Spiking Compound _____ S_1 = _____

	Sample #: _____ UNSP = _____ _____ Approx. M _____ mg QC = _____(ug,mg)/l				Sample #: _____ UNSP = _____ _____ Approx. M _____ mg QC = _____(ug,mg)/l				Sample #: _____ UNSP = _____ _____ Approx. M _____ mg QC = _____(ug,mg)/l				Sample #: _____ UNSP = _____ _____ Approx. M _____ mg QC = _____(ug,mg)/l			
N	M	TH-SP	EX-SP	%R	M	TH-SP	EX-SP	%R	M	TH-SP	EX-SP	%R	M	TH-SP	EX-SP	%R
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
%R																
s																
R.S.D.																

Accuracy Statement:

Using water samples at concentrations of _____ _____ and _____ _____ _____, the recoveries were _____% and _____%, respectively. The standard deviations for percent recoveries were ± _____ and ± units, respectively. The relative standard deviations were _____% and _____%, respectively.

Quality Control Report

DATE _____ PROJECT _____ QUARTER _____

LOG No.	TECHNICIAN	PARAMETER	REPORTED VALUE	ACCEPTABLE (YES OR NO)	COMMENTS

ADDITIONAL COMMENTS:

By _____

EXAMPLE DATA FORMS

Ecosystem Research Institute
Physical Habitat Survey
Coding Sheet

Columns	Instructions
1-6*	Date in order -- year -- month -- day.
7-10*	Time on 24-hour clock that transect measurement began.
11-14*	Project No., e.g., 81-01.
15-18	Transect No., e.g., WR18.
19-22	Survey distance beginning with zero (0) bench mark. Enter to nearest 0.1 meter (cm).
23-26	Elevation read from stadia rod to nearest 0.01 meter (cm).
27-47	Velocity at surface and equal intervals (1 ft., 0.33 m, 0.1 m, etc. to bottom - specify intervals in 0.01 meters on first line of file after transect number.
48-49	Dominant substrate present. Pick the size class from the following list is present in the largest percentage. Enter the letter code for each that is underlined.

Size Class	Largest Dimension
BOulder	>10 cm
CObble	5-10 cm
RUbble	1-5 cm
PEa Gravel	0.5-1.0 cm
SAnd	0.1-0.5 cm
SIlt	0.01-0.1 cm
CLay	<0.01 cm

50	Indicate water's edge by entering E in this column. Enter distance from benchmark (0 point) to waters' edge in cols 15-18 and elevation at water surface in cols 19-22.
51	Enter sample code for periphyton samples. Code as follows:

Sample Code	Dimensions	Area Sampled
Clear	4.6 cm ø	16.6 cm^2
Blue Tube	10.6 cm ø	88.2 cm^2
Ekman Dredge	15x15 cm	225 cm^2

52-53	Enter sample code for benthic invertebrate samples. Code as follows:

Sample Code	Dimensions	Area Sampled
Hess	41 cm ø	1320 cm^2
Ekman	15x15 cm	225 cm^2
Surber	30.5x30.5cm	930.3 cm^2

Sample Code	Dimensions	Area Sampled
Clear Tube X1	4.6 cm ø	16.6 cm^2
X2	4.6 cm ø	33.2 cm^2
X3	4.6 cm ø	49.8 cm^2
Blue Tube	10.6 cm ø	88.2 cm^2

54 Enter sample code for microbiology samples. Code as follows:

Sample Code	Dimensions	Area Sampled
Clear Tube	4.6 cm ø	16.6 cm^2

55 Enter sample code for sediment samples. Code as follows:

Sample Code	Dimensions	Area Sampled
Clear Tube	4.6 cm ø	16.6 cm^2

56 Enter X if water samples are taken.

* On first line of data form for each transect/sample period record the following:

Col	
1-6	Date
7-10	Time
11-14	Project No.
15-18	Transect No.
19-22	Depth Int ---- CM

E.R.I. PHYSICAL HABITAT SURVEY

Date By No.

Sample date	Time	Project no.	Transect no.	Distance (0.1)	Elevation (0.01m)	Velocity (cm/sec).	Dominant substrate	Edge	Samples				
									Per.	Ben.	Mic.	Sed.	H_2O

5.0 TERRESTRIAL FAUNA RESOURCES

5.1 Program Design and Rationale: Objectives

The major objective of the terrestrial fauna monitoring program is to determine if mining and processing of oil shale and related activities significantly affect the structure and function of the local terrestrial ecosystem. Thus, there are three major goals:

- To determine if there is a departure from "normal," defined as ambient conditions during the seven year baseline period.
- To discover if this departure is caused by man's activities or if it is related to natural environmental changes.
- To evaluate the success of reclamation efforts in terms of returning disturbed areas to their original conditions.

5.1.1 Identification of Potential Impacts

The program described below is based on knowledge of what perturbations are expected from development of oil shale and how these perturbations might impact the terrestrial ecosystem. The expected perturbations are:

- surface disturbance - vegetation and soil removal
- noise
- activity
- gaseous air emissions
- dust generation
- leachate contamination of water
- runoff contamination of surface water

These perturbations will influence the terrestrial wildlife community as shown in Figure 1.0-1. For example, vegetation and soil removal required for the facilities will decrease the cover available for wildlife. As a result, local forage and browse will be diminished. Vegetation and soil removal can also cause a reduction in the species diversity of insects and soil invertebrates.

Gaseous air emissions, dust, leachate contaminants, and runoff may affect vegetation and soils in areas not already affected by the construction and operation of the facilities or ancillary structures. In these instances, impact magnitude will vary depending upon duration and type of discharge or perturbation. For example, dust generation and gaseous air emissions may affect the vegetation or soil communities during the operation phase; whereas, leachate or runoff contamination may occur only infrequently. In addition, the construction of the White River Dam will result in impacts to terrestrial fauna in surrounding areas. Consequently, the pathway of impacts will be followed to separate the effects of the Dam from those of oil shale development.

The monitoring program described below, in addition to identifying potential impacts and their causes, will be used to monitor the return of reclaimed areas to a natural condition. This program uses three different methods for impact analysis: hypothesis testing, analysis of interrelationships between components of the ecosystem, and comparison of control and treatment (affected) areas. Hypothesis testing involves statistically detecting departures from baseline conditions. If departures from the baseline conditions are discovered, they will be analyzed to determine if they are caused naturally or by industry. The analysis of interrelationships involves examining the ecological links between the terrestrial fauna segment and other segments of the ecosystem. A study of these interrelationships will be supplemented with comparisons between impacted and control areas that have been shown to be similar in community composition.

5.1.2 Parameters to be Measured

All parameters were evaluated by the criteria listed in Section 1.3 of the Introduction. The parameters that were selected are all state variables (describing ecosystem structure) as opposed to rates or processes (describing ecosystem function). In many cases rates can be inferred from the measurement of the state variables but they are difficult to measure directly. For example, nutrient cycling in the soil is related to the invertebrate activity and, thus to soil invertebrate populations. In addition, many important ecological processes such as primary or secondary consumption are too expensive and time consuming to measure directly and are very difficult to measure accurately indirectly.

Operational Parameters

Breeding Birds

Breeding bird populations will be sampled for: abundance, biomass, distribution, and species diversity, richness and composition. These communities will be sampled because they:

- represent an important component of terrestrial ecosystems, in terms of conspicuousness, energy flow, and community relationships;
- relate closely to ecosystem components that are lower in trophic structure (e.g., seed production or invertebrate abundance);
- may be affected both directly through disturbance or indirectly through energy flow in the ecosystem, and
- are also regarded as being an aesthetic resource.

The baseline period has shown that bird community characteristics are measurable and relate well to other aspects of the terrestrial ecosystem, particularly when bird abundance is broken down into functional groups. Functional group composition also aids in identifying the pathway of an impact.

Spring Migratory Birds

Spring migratory birds will be sampled for abundance, distribution, biomass, and species diversity, richness and composition. Spring migratory birds will be included because they:

- o are highly mobile, only stopping during migration in areas where conditions appear favorable. Thus, they can quickly reflect conditions on the oil shale tracts;
- o help interpret changes in breeding bird populations, and
- o are legally protected.

Reptiles

Reptiles will be sampled for abundance, biomass, distribution, and species diversity, richness and composition. This taxonomic group will be sampled because:

- o although largely inconspicuous, reptiles form a very important part of the cold desert ecosystem;
- o may be closely linked with invertebrate prey communities and with predator populations, and
- o populations have been stable over the seven year baseline period.

Small and Medium-Sized Mammals

Small and medium-sized mammals will be sampled for density, abundance, biomass, distribution, and species diversity, richness, and composition. These mammal communities will be sampled because they:

- o are ecologically important in that they relate to lower trophic levels, particularly primary production and seed resources and to higher trophic levels (predators);
- o are important to monitor in connection with revegetation efforts;
- o are correlated with various vegetation parameters and soil conditions;
- o are indicators of site-specific conditions, and
- o may be affected through changes in primary productivity and through the loss of habitat taken up by project facilities.

Potential Parameters

Foliage Invertebrates

This community will be sampled for abundance, distribution, biomass, taxonomic diversity, and functional group and taxonomic group composition. Invertebrates will be measured because they:

- o are very low in the food chain and have short generation times, thereby responding quickly to environmental disturbance (such as changes in vegetation and air quality); and

- o are the major consumers of primary production and serve as a major food source for many other groups of secondary consumers.

In addition, the foliage invertebrates can be classified into functional groups and thus relationships with vegetation parameters can be established.

Soil Invertebrates

Soil invertebrates will be sampled for abundance, distribution, biomass, species diversity and composition. Soil invertebrates will be included in the monitoring program because they:

- o are important in nutrient cycling;
- o may be able to detect an impact before it is evident in any other component of the ecosystem, and
- o are expected to be impacted by changes in both air quality and water quality.

If changes are observed in the soil invertebrate community, correlation with concurrent soil chemistry, soil microbiology and vegetation monitoring will help determine the cause of change.

Waterfowl

Waterfowl will be sampled for abundance, distribution and species composition. Waterfowl populations are included in monitoring because they:

- o are important mainly for their recreation and economic value; and

- o are potentially affected by changes in water quality resulting from oil shale development.

Raptors

Raptors will be studied for nesting abundance and location. Raptors are important to survey because they:

- o are at the top of the food chain and reflect changes in their prey species;
- o are important from an aesthetic standpoint and are legally protected, and
- o raptor populations are not only affected indirectly by changes in prey populations but may also leave the area because of direct affects such as noise, activity and surface disturbance.

Threatened and Endangered Species

The abundance of wintering bald eagles will be recorded because of their role as a carnivore, their aesthetic value and legally protected status. Bald eagles wintering along the White River are most likely to be directly affected by development, although indirect impact through the aquatic food chain is also possible.

Large Mammals (Big Game)

Big game mammals will be sampled for abundance and distribution. Large mammals will be included in the monitoring program because they:

- o are a recreationally important resource; and

- o are sensitive to both direct impacts as a result of disturbance, and indirect impacts as a result of changes in the vegetation structure.

Contingency Parameters

Chemical Uptake

A sample of small mammals and foliage invertebrates, primraily grasshoppers, will be analyzed for levels of heavy metals, organics, pesticides, and herbicides. The measured values will be compared to background levels obtained from the literature. These compounds will be measured because they:

- o will help identify the cause of a change in small mammals, foliage invertebrates, or perhaps bird populations, and

- o elevated levels could be caused by air emissions, leachates, processed shale, or pesticide or herbicide treatment during reclamation.

Bats

Bat populations will be sampled for abundance, biomass and species richness and composition. Bat sampling would be effective in a contingency situation because:

- o Bats reflect levels of emerging aquatic invertebrates and other aerial invertebrates and thus can help interpret changes in foliage invertebrates of birds (especially aerial insectivores). Bat abundance was correlated with aerial insectivore abundance during the baseline period ($r = .97$ $p < 0.01$).

5.1.3 Sampling Locations

Sampling will be conducted at nine locations. This includes an alternative sampling location, R-4, which will be used if the primary riparian sampling area, R-2, is flooded by the White River Dam (Figure 5.1-1).

Each sampling location will include a 1 km transect used for bird, medium and large mammal, reptile, foliage invertebrate and soil invertebrate sampling and a 165 m x 165 m grid used for small mammal trapping. Transects are marked at each end and at each angle by a permanent steel fence post and are also marked intermittently along the transect by colored flagging tape. Grids are marked at four corners by permanent steel fence posts and trap locations along the edge of the grid are marked with six-inch high stakes. Waterfowl and bald eagle surveys will be conducted along the White River from Asphalt Wash to Cowboy Canyon.

Selection of these sampling locations is based on five criteria:

1. Habitat type. Sampling locations were placed in representative stands of the four habitat types that have been defined on the oil shale tracts: sagebrush-greasewood; shadscale-sagebrush; juniper, and riparian. Three sampling locations have been placed in sagebrush-greasewood because this is the habitat type that will be most affected by processed shale disposal.

2. Spatial relationships. Sampling locations were selected so that they adequately survey tracts Ua and Ub.

3. Control/treatment. Sampling locations were selected so that some locations are more likely to be affected by potential impacts of oil shale development and others may not be impacted

at all. The latter stations will serve as control sites for comparison purposes.

4. Location of other sampling sites. Sampling locations are adjacent or identical to sampling locations used for other portions of the monitoring program so that terrestrial fauna data can be correlated with other biotic and abiotic data.

5. Schedule of development. Sampling locations were also chosen close to development activities so that they will reflect potential impacts and help evaluate reclamation success.

5.1.4 Sampling Schedule

A primary consideration in selecting sampling periods was to ensure compatibility with data collected during the baseline period. The sampling schedule is summarized in Table 5.1-1. This schedule for operational parameters is subject to change in time and frequency (following OSO approval) if evidence of contamination is determined from any discipline. Other considerations for each parameter are defined below.

Operational Parameters

Breeding Birds - June (first two weeks)

The baseline period has shown that by the first two weeks of June, all breeding birds have arrived on the site and a minimum number of young of the year are apparent. Bi-monthly sampling during the baseline has shown June samples to be the least variable and thus the best for detecting change. June bird abundance also predicts annual abundance ($r^2 = .95$, $p < 0.001$).

START OF WATERFOWL AND BALD EAGLE SURVEY

END OF WATERFOWL AND BALD EAGLE SURVEY

R-4

R-2

S-4

S-1

J-3

G-2

G-3

J-1

G-1

LEGEND

TRANSECT

GRID

NOTE:
TERRESTRIAL FAUNA SAMPLING LOCATIONS SHOWN ON TRANSECTS FOR BIRDS, LARGER MAMMALS, REPTILES, FOLIAGE AND SOIL INVERTEBRATES, GRIDS FOR SMALL MAMMALS AND START AND END POINTS FOR WATERFOWL AND BALD EAGLE SURVEYS.

N

TERRESTRIAL BIOLOGY MONITORING STATIONS

FIGURE 5.1-1

TABLE 5.1-1

SAMPLING INTENSITY AND SCHEDULE OF
MONITORING TERRESTRIAL FAUNA PARAMETERS(1)

Parameter	Number of Locations	Sampling Unit	Replications	Time of Day	Time of Year
Operational Parameters					
Breeding Birds	8(2)	1 km transect	5 (days)	sunrise to sunrise + 3 hrs	June
Spring Migratory Birds	4	1 km transect	3 (days)	sunrise to sunrise + 3 hrs	April
Reptiles	8	1 km transect	5 (days)	noon + 3 hrs	June
Small Mammals	8	Grid, 2.72 ha 144 traps	5 (nights)	overnight	August
Medium Mammals	8	1 km transect	5 (days)	afternoon-evening	August
Potential Parameters					
Foliage Invertebrates	8	Shrub	20 shrubs(3) 10 shrubs	mid-day	April through October, inclusive
Soil Invertebrates	8	4 soil samples under 1 shrub	6 shrubs	mid-day	April, June, August, October

TABLE 5.1-1 (cont.)

Parameter	Number of Locations	Sampling Unit	Replications	Time of Day	Time of Year
Waterfowl	1	1 trip down river	3	mid-day	April
Raptors	Ua and Ub and 1 mi. perimeter	N/A	N/A	N/A	February, April
Large Mammals	8	1 km transect	3 (days)	afternoon-evening	August, February
	1	Overflight	1 (day)	morning	February
Threatened and Endangered Species	White River	N/A	N/A	N/A	February
Contingency Parameters					
Chemical Uptake	8	Specimens	5	N/A	August
Bats	1	Trap night	5	night	August

(1) Schedule subject to change depending upon incorporation into long-range program.
(2) The 1982 program will include nine transects (see text).
(3) See text for details (Section 5.2.1).

Spring Migratory Birds - April

The April bird sample includes:

- o birds that are permanent residents which are important in interpreting changes in the June breeding bird sample; and
- o spring migrants which stop temporarily on the tracts.

Reptiles - June

June encompasses the peak of reptile abundance on the tracts.

Small Mammals - August

Bi-monthly sampling of small mammals during the baseline period has shown the August sample to be the annual peak of abundance as well as best represent total species composition.

Medium-sized Mammals - August

Baseline data has demonstrated a peak of medium-sized mammal (mainly Lagomorph) activity during August. As abundance is generally low, higher abundances produce the best results for statistical tests.

Potential Parameters

Foliage Invertebrates - April through October

Foliage invertebrates will be sampled monthly throughout the growing season until it is determined that a less extensive sampling schedule will produce results which relate well to other parameters (e.g., insectivorous birds, plant production).

Soil Invertebrates - February, April, June, August, October

Soil invertebrates will be sampled throughout 1982 until it is determined that a less extensive sampling schedule will produce results which relate well to other parameters (i.e., soil microbiology, soil moisture). In many areas, much of the biological activity in soil takes place during winter. The OSO will be consulted following the 1982 sampling period to select the proper sampling frequency.

Waterfowl - April

Transect observations have shown that April is the peak of waterfowl use on the White River. Canada geese (Branta canadensis) initiate nests during April and other transient species are present.

Raptor Nests - February and April

Nest searches will be made in February 1982, when golden eagle and Great Horned owl nesting begins and in April 1982, when most of the smaller raptors will have nests.

Threatened and Endangered Species - February

The only threatened and endangered species of concern, the bald eagle, winters along the White River. During the baseline period they have been most conspicuous during February. Investigations will take place during 1982.

Contingency Parameters

Chemical Uptake - August

Chemical uptake will be analyzed in small mammals and invertebrates collected during August. Small mammals will be collected as part of

regular small mammal sampling. Grasshoppers, for which there are baseline data in the literature on chemical uptake, are most abundant during August.

Bats - August

August sampling of bats includes young of the year as well as migrants and thus reflects reproductive levels which relate to food supply. Thus, August sampling is useful in determining the pathway of an impact.

5.1.5 Fulfillment of Objectives

The objectives, to detect change in the terrestrial system and to determine the cause of change, can be met by the above sampling regime. Parameters to be measured are, in general, community level parameters that integrate information on smaller subsets of the system. Thus, if significant changes occur in a subset, they will be detected by the community level parameters. The cause of changes can be determined by more detailed analysis of the data, by looking at relationships between parameters, and by further observations, as described in Contingency Sampling.

Standard statistical procedures will be used on data collected by the described methods. Analysis of baseline data has shown that differences in the above parameters between habitat types, between months, and between years can be detected. These differences have been related to probable causal factors. Thus, it is expected that potential changes due to development can also be detected, and the causes can be traced to man-made perturbations or to natural variation in environmental variables.

5.2 Methods

This section describes the methods and techniques that have been used during the baseline period and will be followed during the monitoring program so that results are comparable. Because much of the data is based on observations, it is important that the specific rules pertaining to observations are followed. The following sections detail the methods of data collection, sampling schedule and data handling for each one of the parameters that have been selected for monitoring.

5.2.1 Method of Data Collection and Schedules

Breeding Birds

Breeding birds will be counted on 1 km-long flushing transects in each sampling location. These counts will be conducted between sunrise and three hours after sunrise for five consecutive days in June. The observer will walk the center line of the transect and search the area in front of him, usually within 100 meters of the center line. Positive identification of vocalizations will be used for species richness determinations but will not be included in the abundance estimates. Data recorded for birds seen will include: species identification; number of individuals; perpendicular distance from the center line of the transect; maximum and minimum temperatures; wind speed and other weather conditions; bird activity (feeding, stationary, etc.), and substrate (tree trunk, tree foliage, shrub canopy, etc.).

Spring Migratory Birds

Migratory birds will be sampled by the same method as breeding birds except that transects will be walked for only three consecutive days rather than five and only four sampling locations will be used (G-1, S-1, J-1 and R-2 or R-4). Data similar to that listed above (breeding birds) will be recorded.

Reptiles

Reptiles will be counted along the same transects used for breeding birds. These surveys will be conducted between 0900 and 1500 hours. The observer will walk the center of the transect and search the ground in front of him, usually within three meters of the center line. Transects will be walked for five consecutive days. Data similar to that listed above (breeding birds) will be recorded.

Small Mammals

Small mammals will be trapped on grids measuring 165 m x 165 m covered with 144 Sherman live traps (7 cm x 9 cm x 24 cm) in a 12 x 12 array, with 15 meters between each of the traps. Traps will be placed in the shade of a shrub if this is possible without moving them more than one meter from their designated position. Traps are baited with rolled oats or barley, a small amount of which is scattered outside the trap. For five consecutive nights traps will be set and baited in the evening and checked and closed in the morning.

Each small mammal captured will be identified to species and ear tagged with a #1 Monel tag and weighed to the nearest gram. Sex and age (juvenile or adult) will be determined as well as reproductive condition (pregnant or lactating) and physical condition. The trap number will be recorded to analyze movement between captures. Supplemental information recorded will include soil condition (wet or dry), maximum or minimum temperature for the day, wind, time of day, and number and location of sprung or inoperative traps. Traps are checked before noon to minimize trap mortality due to heat.

Medium-Sized Mammals

Medium-sized mammal populations will be sampled on the same transects used for birds. Sampling will occur during five consecutive days in August. Data to be recorded include species identification, number of

individuals, perpendicular distance, and weather conditions. Any other species or sign of species (e.g., tracks) seen on the tracts will be recorded with habitat type for compilation of a species list.

Foliage Invertebrates

Sampling will be done primarily on Artemisia tridentata but also on other dominant shrubs and trees in each habitat. Twenty plants of big sagebrush will be sampled along each of the bird transects. An additional 10 plants will be sampled of Chrysothamnus nauseosus in sagebrush-greasewood and riparian, C. viscidiflorus in juniper, Sarcobatus vermiculatus in sagebrush-greasewood, Juniperus osteosperma in juniper, and Atriplex confertifolia and Tetrademia spinosa in shadscale-sagebrush. Plants for sampling will be selected at random along each bird transect.

Data recorded with each sample collection will include: height of shrub; diameter of shrub; time; cloud cover; temperature, and wind direction and speed.

Two methods of collection are currently being tested: sweep netting and beating. Sweep netting involves 10 to 20 strokes (depending on plant size) through the entire plant taking care not to destroy the shrub. An upward swinging stroke is preferable as it will catch those individuals which drop from the canopy of the shrub. Beating involves a shallow net held under the parts of the shrub to be sampled which is rapidly hit three to five times with an axe handle knocking the invertebrates into the net. In both techniques the contents of the net are killed by cyanide, placed in a bag, and refrigerated to minimize dehydration. The invertebrates are moist until sorting is complete so that they can be manipulated. Drying occurs after identification is complete.

In the lab, invertebrates are first separated from debris in the sample. Invertebrates are then identified to family, genus, or species, tallied, and placed in one of nine functional feeding group vials. The functional vials are dried for at least 24 hours at 35-45°C. The invertebrates in the vials are weighted to 0.01 mg on a balance to obtain biomass within each functional group.

Soil Invertebrates

Soil samples will be collected under big sagebrush (Artemisia tridentata) along the same transects used for birds. Six shrubs will be sampled on each transect and then flagged to avoid repeated use.

Samples will be taken with a coring device sold commercially for use in planting garden bulbs. The exact size is immaterial as long as it is known and constant. Four cores are taken approximately three-fourths of the distance from the center of the shrub to the edge, and approximately equi-distantly spaced around the shrub. The corer is projected through the litter layer and 5 cm into the mineral soil, if possible. The four cores are placed in a single labeled plastic bag. Protection from extremes of temperature and direct sun is then critical. The shrub is then measured for height and maximum diameters for calculation of shrub volume. The soil temperature is taken on the sunny and shaded sides of the shrub. All materials are transported to the laboratory for analysis, as quickly as practical.

Prior to analysis, the samples are maintained at 4°C to minimize biotic and moisture changes. The sample is thoroughly mixed so that it becomes homogenous. Two extractions will be done on each sample - one for nematodes and one for arthropods (primarily mites).

For the nematode extraction, 25-35 g of material is weighed and placed in a segment of polyvinyl chloride pipe (4.5 cms diameter) with a double layer of nylon mesh (from nylon stockings) attached to one end.

The pipe segments are fastened vertically over labeled beakers (250 ml) approximately one half filled with tap water. Pipe segments are lowered into the beakers so that the nylon mesh just touches the surface of the water. Then, a cube of 3% saltwater ice is placed in each pipe. Nematodes, repelled by the melting salt-water, migrate downward into the beakers. After three to four hours, the pipes are removed from the beakers, and 3 ml of formalin is added to kill the nematodes.

After at least 12 hours, the excess liquid in each beaker is very carefully aspirated off without disturbing the bottom material until only a few milliliters remain. The label on each beaker is then transferred to a vial containing 5 drops of a 1:1 mixture of glycerin:water, enough rose Bengal to turn it a deep cherry red, and a few crystals of thymol, a microbial inhibitor.

Samples are then concentrated by removing excess liquid and transferred to a microscope slide covered with a glycerin-jelly-water mixture. Nematodes on the slides are then identified to species and counted using a phase-contrast microscope.

After the nematode extractions are in progress, the arthropod extractions are begun. The material remaining in each bag (typically 370-700 g) is weighed and placed in a standard Tullgren modification of the Berlese funnel. Forty-watt light bulbs are placed above each funnel and the extraction is allowed to continue for three days. Arthropods are collected in vials containing a 60:5:35 mixture of isopropanol: glycerin:water. Afterward, the dried material is weighed with weight loss used as an indication of soil moisture. For identification and counting, the vial contents are transferred to a Syracuse dish and examined under a dissecting microscope.

For both nematodes and arthropods, abundance will be expressed as total numbers per cm^2 of soil surface area. Species richness and Shannon-Weiner species diversity will also be calculated.

Waterfowl

Waterfowl populations will be sampled by counting all waterfowl observed from a canoe between Cowboy Canyon and Asphalt Wash (Figure 5.1-1). This stretch of the river will be floated for three consecutive days in April. The river will be divided into 1 km sections on a map. All waterfowl in each 1 km section are then recorded and particular attention will be paid to birds that flush and fly down river so that they are not recorded twice. Supplemental information recorded will include: location of nests, and presence of young or eggs.

Raptors

In February and April of 1982, the tracts will be searched on the ground and from the air to locate raptor nests. In subsequent years, known raptor nests will be checked and additional nests will be mapped. Special attention will be paid to golden eagle nests. For some species (sharp-shinned hawks and kestrels) the territory of a pair of birds may be mapped as opposed to plotting the actual nest site. Data recorded on each nest will include: active or inactive; phenological condition, and if possible, the number of eggs, or chicks. Subsequently, surveys will be conducted periodically depending upon inclusion with the long-term monitoring program.

Threatened and Endangered Species (Wintering Bald Eagles)

During February 1982, and occasionally thereafter, an aerial flight along the White River from Asphalt Wash to Cowboy Canyon will be made and the numbers and locations of bald eagles and their nests will be noted.

Larger Mammals

Large mammals will be surveyed in February using aerial census techniques. These procedures will be supplemented with transect observations in August and maps of all other observations throughout the year.

Chemical Uptake

Small mammals and invertebrates will be collected in areas where other data suggest a potential impact. These samples will be analyzed for B, Cd, As, Ni, Hg, Zn, Mg, Mo, Pb, F, Fe, and Se which will also be analyzed in plants (Section 3.0, Vegetation). Analysis will also be done for organics from processed oil shale and organochlorines (pesticides and herbicides) if such compounds are present in the area being sampled. Analysis will be done by an independent laboratory using appropriate techniques.

Bats

Bats will be sampled on a series of small ponds in Asphalt Wash. Mist nests will be placed across areas of open water for five consecutive nights and checked every 15 minutes. Each bat caught will be identified, sexed, weighed, and measured. Flying invertebrates will be collected concurrently using a light trap.

5.2.2 Materials Needed

Materials needed for each sampling procedure are detailed as follows:

Breeding birds: binoculars, maximum and minimum thermometer, wind meter.

Spring migratory birds: same.

Medium-size mammals: same as birds.

Reptiles: same.

Small mammals: Sherman live traps, bait, gram scale, ear clips, pliers.

Foliage invertebrates: hand anemometer; pocket case thermometer; #4 paper bags; meter tape; stapler; paint can with cardboard plate over cyanide bag; paint can opener; small muslin bags; KCN - Potassium cyanide granules; base-mounted Tally meters - five counting units; flagging; #5 watchmakers forceps; locking forceps; camel hairbrush #0; white enamel pan (13-1/4" x 9-3/8" x 5/8"), binocular microscope with 10 and 20x objectives; plastic Petri dishes (3-5/8" dia.); dessicator; aluminum weighing pan; USA standard testing screens (size nos. 5, 35, 60); sweep net(1), and beating net(2).

Soil invertebrates: coring device; flagging; plastic bags; labels; cooler; tape measure; soil thermometer; PVC pipe extraction vessels; beakers; vials; stoppers; dissecting microscope; phase-compound microscope; pipettes; Siliclad-coated Petri dish; eyelash; scale; Tullgren modified Berlese funnels; 40-watt light bulb; Syracuse dish; platinum wire; microscope slides; cover slips, 3% salt-water ice, formalin; glycerin; rose bengal; thymol; glycerin jelly; isopropanol; Hoyer's medium.

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(1) Because desert shrubs have dense canopies that bristle with sharp spines, the stock sweep net designed for crop situations is not a satisfactory sampling tool. The standard mesh net has been replaced with the khaki twill reinforced with heavy weight denim around the rim. The standard lightweight rim has been replaced with a heavy steel rim.

(2) A greatly modified beating net has also been designed. The rim is approximately 22 inches in diameter and is made of lighweight half-inch band aluminum. The net is made of lightweight muslin, and is formed into a shallow bowl with a pocket on the bottom. The handle is a short, wooden dowel.

Waterfowl: binoculars, canoe, maps of White River.

Raptors: spotting scope, climbing gear.

Large Mammals and Threatened and Endangered Species: aircraft (chartered).

Chemical Uptake: analysis by independent laboratory.

Bats: mist nets, waders, gram scale, calipers, head lamps.

5.3 Quality Assurance/Quality Control Procedures

5.3.1 Quality Assurance Program Design

Quality of data received from field personnel is maintained by attention to three areas: (1) coding form design to minimize data recording errors; (2) syntactic data verification to maximize recognition of data errors; and (3) command structure for standard analyses to minimize errors in data handling and processing.

Field coding forms are designed with several concerns in mind: (1) ease of use for field personnel; (2) ease of data entry to the computer; and, (3) complete identification of each line of data. These attributes minimize errors created during data acquisition.

Data files are proofed by various programs which check for syntactic errors in the data. Several fields in the file are checked against a list of valid codes or the codes found are tabulated for a manual check. Where possible, alphabetic codes are preferred to numeric codes to enhance detection (recognition) of errors. Redundant fields of data (as in date, location fields) are duplicated automatically in continuous blocks to prevent loss of integrity of sample units by data entry errors.

Command structures consist of a series of commands which supervise the entry, verification, and processing of standard categories of data. This insures that specific instructions to utility programs (such as duplication and sorting programs) are not mistyped. It additionally guarantees a standardized naming system for all files generated by processing a data set.

Short-term storage of data is on-line with long-term storage on magnetic tapes (as well as backup magnetic tape storage of on-line data). Raw data files are stored in their original format to maintain readability.

5.3.2 Quality Control Procedures

Samples will be collected from the same location from year to year. This is guaranteed by marking all transects and grids with permanent steel stakes. Observer bias can be partially controlled by the following measures: (1) species identification is aided by use of dichotomous keys and other identification aids including conversations between observers and consultation with published sources; (2) distance estimates will be checked by occasionally pacing off observer estimates; (3) unknown species that are collected, for example, from trapping, will be preserved and sent to a specialist for identification; (4) differences in technique can be minimized by applying uniform sampling procedures of data collection; (5) data will be checked after it is entered on a coding form.

Quality control for foliage invertebrates involves two procedures. First, the two sampling techniques, sweep netting and beating net, are occasionally used in the same area for comparison. Second, on a few samples, the invertebrates remaining on a shrub after sweep netting are collected by cutting down the shrub, placing it in a paper bag with cyanide and collecting all invertebrates. By following these procedures, the accuracy and precision of sweep netting can be assessed.

5.4 Data Analysis

5.4.1 Data Management

Field data are recorded in notebooks in the field and transferred to coding sheets within the same day or as soon as possible. This facilitates making corrections and filling in deletions before the details of each day are forgotten. Data from each sampling session (month) will be typed into a computer tape, go through quality assurance procedures, and then summarized and stored.

5.4.2 Data Reduction

Before statistical analyses are carried out, a summary is prepared for each dataset. Summaries are done by computer programs written specifically for each type of data. These programs are described below.

Transect Summary

The transect summary program summarizes all data that are recorded from transects (breeding and migratory birds, medium-size and large mammals, and reptiles). This summary produces for each five day sample session and each transect the following figures used in later statistical data analyses: (1) total number of animals seen (includes unidentified animals); (2) total number of species that are identified; (3) Shannon-Weiner diversity; (4) total biomass of all identified species. Biomass is based on average weights obtained from the literature.

The diversity index are calculated from Odum (1971).

Trap Summary

The trap summary program is used to summarize data obtained from the small mammal trapping. It produces for each five-day sampling session on each sampling location the following summary figures:

(1) The total number of individuals caught.
(2) Total number of species caught.
(3) Shannon-Weiner diversity.
(4) Total biomass based on specimens that are weighed and on weights from the literature.
(5) A list of all species captured with abundance.
(6) A breakdown by age, sex, reproductive and physical condition within any species.

Foliage Invertebrate Summary

This summary calculates for each transect:

(1) Total abundance and biomass.
(2) Abundance and biomass in each functional group.
(3) Taxonomic group diversity.

Soil Invertebrate Summary

This summary program will calculate for each transect:

(1) Total density of organisms.
(2) Species diversity.
(3) Species richness.

5.4.3 Statistical Procedures

The major statistical procedure used for detecting changes in terrestrial fauna is two-way analysis variance (ANOVA). An ANOVA table is created for each major variable with treatments consisting of different years and blocks consisting of different habitats. The major variables on which the ANOVA is done include abundance, biomass, species richness, and species diversity for breeding birds, migratory birds, large mammals, reptiles and small mammals plus immature/adult ratio for small

mammals. The two-way analysis of variance enables one to detect differences between years (i.e., pre-development and post-development) and between control areas and impact areas. The hypotheses being tested by ANOVA are:

H_0: There is no difference in the variable being tested among years.

H_0: There is no difference in the variable being testing among control and impacted areas.

When one of these hypotheses is rejected a least significance difference test (LSD) (Steele and Torrie 1960) enables a determination of which years or which habitat types are responsible for significant differences. Once significant differences are detected by ANOVA and LSD, further ANOVA's can be carried out on individual transects to see if a specific transect has changed between years while others have not. Similar analyses can also be done with the individual functional groups (aquatic species, predators, flying insectivore, foliage insectivores, trunk/branch insectivore, granivores and omnivores). All tests will use a significance level of $p = 0.05$ (see Tables 5.4-1 and 5.4-2 for example of ANOVA tables). This alpha value is considered appropriate based upon the large data base accumulated by WRSOC. It is planned prior to retort operations to reevaluate the data base to determine if this level is suitable for impact identification.

Foliage invertebrate and soil invertebrate data will also be analyzed by ANOVA and LSD. Hypotheses that will be tested with the first year data are:

H_0: There are no differences in invertebrate abundance and diversity between habitat types.

H_0: There are no differences in invertebrate abundance and diversity between months.

TABLE 5.4-1

June bird abundance (No/5 km) analysis of variance and pairwise comparisons using least significant difference (LSD). LSD is carried out only if a significant difference is found by the analysis of variance.

	Treatments (Year)						
Blocks (habitat type)	1975	1976	1977	1978	1979	1980	1981
Sagebrush-Greasewood	133	80	47	57	54	91	92
Juniper	119	109	48	49	76	91	75
Shadscale-Sagebrush	86	78	42	50	46	49	42
Riparian	500	318	356	300	229	222	225

ANOVA	df	SS	MS	F
Treatment	6	33800	5630	2.67*
Block	3	293000	55500	27.8**
Error	18	37900	2100	
Total	27	364000		

		Difference Between Means					
	$\bar{x}$	1979	1981	1980	1978	1977	1976
1975	209.5	108.2**	101.0**	96.2**	95.5**	86.3*	63.2*
1976	146.3	45.0	37.8	33.0	32.3	23.1	
1977	123.2	21.9	14.7	9.9	9.2		
1978	114.0	12.7	5.5	0.7			
1980	113.3	12.0	4.8				
1981	108.5	7.2					
1979	101.3						

* $P < 0.05$
** $P < 0.01$
$LSD_{.05} = 68.1$
$LSD_{.01} = 93.4$

TABLE 5.4-2

Small mammal density (No/ha) analysis of variance and pairwise comparisons using least significant difference (LSD). LSD is carried out only if a significant difference is found by the analysis of variance.

	Treatments (Year)						
Blocks (habitat type)	1975	1976	1977	1978	1979	1980	1981
Sagebrush-Greasewood	26.9	42.5	9.5	13.9	9.9	22.4	23.6
Juniper	16.9	32.7	3.0	4.2	8.0	7.4	16.2
Shadscale-Sagebrush	18.8	47.4	4.4	9.8	7.0	27.6	21.0
Riparian	9.6	33.8	3.7	9.2	8.2	23.2	14.0

ANOVA	df	SS	MS	F
Treatment	6	3114	519.0	28.71*
Block	3	343.8	114.6	6.339*
Error	18	325.4	18.08	
Total	27	3783		

		Difference Between Means					
Year	$\bar{x}$	1977	1979	1978	1975	1981	1980
1976	39.1	33.9**	30.8**	29.8**	21.1**	20.4**	18.9**
1980	20.2	15.0**	11.9**	10.9**	2.2	1.5	
1981	18.7	13.5	10.4**	9.4**	0.7		
1975	18.0	12.8	9.7**	8.7**			
1978	9.3	4.1	1.0				
1979	8.3	3.1					
1977	5.2						

* $P < 0.05$
** $P < 0.01$
$LSD_{.05} = 6.3$
$LSD_{.01} = 8.7$

Relationships between parameters, for example, foliage invertebrates and breeding birds, will be analyzed to determine the pathway of an impact. The following hypothesis will be tested for parameters between which a relationship has been established during the pre-development period:

H_0: The mean value of one parameter does not change with the other parameter.

This hypothesis will be tested using the t statistic and standard regression and correlation techniques. Analysis of interrelationships is discussed further in Chapter 8.0.

Data from the migratory waterfowl surveys along the White River will be analyzed by one-way analysis of variance comparing data collected among years. Further analysis using 1 km sections of the river will help pinpoint an impact.

Raptor nesting data and wintering bald eagle data will be mapped and analyzed qualitatively. Change will be identifed by either a disappearance of the important species or a change in location of previously observed eagles. In addition, the results of the large mammal surveys will be summarized to show the existence of trends.

A qualitative procedure will be used to analyze species presence of birds, mammals and reptiles. After each sampling period, the list of all species observed on the tracts will be compared with lists of species that have been consistently seen over seven years of study. This list includes 40 breeding birds, 34 spring migratory birds, 14 mammals, and 8 reptiles. These species are regarded as major components of the vertebrate communties on the tracts and are expected to be present every year.

5.5 Development of Contingency Monitoring

The identification of the potential development impacts leading to development of contingency plans as they relate to the terrestrial fauna is an iterative process. The process is interconnected with the monitoring of ecosystem relationships described in Section 8.0, Analysis of Interrelationships. It should be noted that the processes described below can be used not only for detecting impacts from development but also for evaluating the success of reclamation efforts on disturbed areas.

The first step of the process is to determine if there is a change in one of the measured parameters. This is done by statistical measures described under Section 5.4.3 or by simple inspection of the data as in the case of raptors, threatened and endangered species and large mammals. This step tests the primary hypothesis:

H_0: The variable being tested has not changed during the most recent sampling session.

It also involves testing secondary hypotheses concerning the different habitat types and their associated vertebrate communities. These hypotheses have been developed from analysis of the baseline data. Examples of these secondary hypotheses are:

H_0: Bird abundance, species richness and species diversity are equivalent among habitat types.

H_0: Reptile abundance is equivalent among habitat types.

H_0: Small mammal density, biomass, species richness and diversity are equivalent among habitat types.

The subsequent steps in the iterative process help determine if a change that has been identified initially is caused by development activities or is related to natural environmental variables.

5.5.1 Critical Values

The rejection of a null hypothesis will serve as the critical value for impact identification. Thus, a critical value will not be numerical but a probability ($p = .05$) equivalent to a type 1 error (the probability of rejecting the null hypothesis when it is, in fact, true).

In the event of rejection of a null hypothesis, the parameters involved will be correlated to other parameters to determine if they also have deviated from normal levels. If necessary, additional sampling will be initiated.

5.5.2 Contingency Plan

The subsequent steps in the logical progression of impact identification are used to determine if a change that has been identified initially is caused by development activities or is related to natural environmental variables.

The first action taken involves the series of interrelationships beween variables that is described in Chapter 8.0. A change that is found in a variable is analyzed within the framework of the previously determined relationships between that variable and other variables within the ecosystem. If the departure from baseline conditions can be related, directly or indirectly to a naturally varying driving variable, such as precipitation or temperature, the departure is classified as resulting from natural variation and not from a development-related perturbation.

Analysis of interrelationships will be supplemented by comparing treatment or impacted areas to control areas. Impacted or treatment areas will be identified from analysis of other data (e.g., air quality monitoring and modeling or water quality). These will be compared to non-impacted areas by analysis of variance and multiple mean comparison.

Comparisons will be made only between sampling sites that were similar in bird or mammal community composition based on similarity indices calculated during the pre-development phase. The comparison of control and treatment areas will help identify the cause of the impact.

If analysis of interrelationships and control/treatment comparisons do not identify the cause of an impact, the next action is to design and carry out experiments or further data collection to localize the source of change. This might involve increasing the frequency or location of sampling or submitting the data to further analysis.

Literature Cited

Odum, E.P. 19/1. Fundamentals of ecology (2nd ed.). Saunders, Philadelphia, Penn. 574 pp.

Steele, R.G.D. and J.H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, New York. 481 pp.

6.0 WATER RESOURCES

The development of the water resources monitoring plan is essential to develop systems and strategies which will delineate contaminants from oil shale development and their impact on the hydrologic environment. As a result, an initial water resources program has been designed to fulfill the anticipated information needs which will lead to final (Phases II, III) water resources monitoring design. Accordingly, the following program constitutes a design framework based on Phase I development activities and includes surface water, ground water, and precipitation/evaporation monitoring (Section 6.6). All the above components will be interrelated to provide a picture of the hydrologic environment as they relate to the WRSP.

6.1 Program Design and Rationale

The water resources monitoring program has been designed to document and assess potential project-related impacts on the hydrologic environment. To fulfill this objective, the water resources monitoring program will collect site-specific data on surface and ground water throughout the duration of the project. Specifically, the water resources program will be:

- o flexible and responsive to observed changes;
- o in compliance with federal, state and local regulations;
- o capable of differentiating between natural and project-related perturbations via establishment of control and treatment stations;
- o able to identify and provide timely notice of project-related impacts;
- o able to gather information which can be statistically and graphically analyzed to determine variations from baseline conditions;

- o able to determine the effectiveness of mitigation measures, and
- o cost-effective.

The water resources monitoring locations have been situated so as to detect (1) unplanned point discharges, such as accidental spills or leaks from retention dams or impoundments; (2) non-point discharges such as runoff from areas of road construction and other project activities, and (3) from point and non-point sources into local ground water systems.

Surface Water

Surface water gauging stations and water quality sampling sites will monitor the movement of water quantity and water quality near the project site. Gauging station sites adjacent to, and upstream of, the project site will serve as control stations. These sites are unaffected by WRSOC activities and monitor natural (or non-project related) hydrologic fluctuations. Stations have also been chosen downstream of the tracts, and therefore, are designated as treatment stations. These potentially impacted sites will monitor the effects of project contamination that might occur from each drainage basin of concern (see Section 6.1.1). Comparison of control and treatment station data will provide a means of isolating project-related perturbations from natural occurrences.

Ground Water

The monitoring program will detect project-related changes which may occur in ground water quality and storage through the implementation of control and treatment sites. The ground water sites will, in addition, detect contamination before a significant build-up occurs in the system. This monitoring program will focus on the alluvium-bedrock interval for the following reasons:

- The earliest signs of potential ground water impacts will occur and be detected within the canyon alluvium, many years prior to any possible seepage to the Birds Nest Zone.

- Waiting for contaminants to reach the Birds Nest Zone would delay any effective mitigation planning and implementation to protect a useable aquifer, and would divert monitoring attention from the canyon alluvium where problems could be corrected before serious contamination would occur.

- Any water quality data collected in the Birds Nest Zone would be inappropriate in terms of assessing facility impacts, because it is unlikely that the relatively small anticipated volumes of leachates will penetrate hundreds of feet of compact bedrock.

- A potential exists that well holes drilled through the alluvium that penetrate to the Birds Nest Zone could inadvertently establish a direct and permanent hydraulic connection between the project area and the ground water.

Site alluvium has therefore been selected as the preferred or primary sampling medium for ground water quality monitoring. It is believed that the proposed configuration will satisfy the intent of applicable regulations regarding ground water protection.

6.1.1 Characterization of Potential Impacts

The potential impact in each of the four affected drainage basins (Southam Canyon, Plant Site, Evacuation Creek, and White River) is largely dependent upon the proposed activity for each drainage area. For instance, the monitoring program in Southam Canyon is designed to detect potential effects associated with the processed shale pile. Thus, characterization of potential impacts is presented below on a

site-specific basis. The complete pollution potential ranking for all drainage areas is shown in Table 6.1-1 (adapted from EPA 1979).

Southam Canyon

Southam Canyon will be the final disposal site for all processed shale and, therefore, will require special consideration because of the potential long-term leaching action and the mobility of chemical contaminants in the processed shale pile. A number of recent studies have provided information on the possible composition of leachate from processed oil shale (Harbert, Berg and McWhorter 1979; McKell, Van Epps and Richardson 1979) Table 6.1-2 lists some of the chemical parameters and their concentrations.

The sources of pollutants and toxicity of the pollutant are grouped into three categories or priority rankings. The three criteria used to develop the source-pollutant ranking are:

- Mass of waste persistence, toxicity and concentration
- Potential mobility
- Known or anticipated harm to water use

A preliminary priority ranking of potential pollution sources and causes and potential pollutants was then developed. The highest priority sources were asssociated with the processed shale disposal area and include processed shale and process-related waste water used to moisten the processed shale. Retention dams located below the processed shale pile are also in the highest rank. Associated with these sources are several chemical constituents, considered the most significant potential pollutants, including: total dissolved salts; selected macroinorganics (sodium, sulfate, and chloride); selected trace elements (arsenic, fluoride, and selenium), reduced sulfur compounds and organics.

TABLE 6.1-1

PRELIMINARY RANKING OF POLLUTANT SOURCES AND POLLUTANTS FOR OIL SHALE TRACTS U-a and U-b

Source Pollution Ranking	Potential Pollution Source	Potential Pollutant Ranking		
		Highest	Intermediate	Lowest
Highest	Processed shale	TDS, Na, SO_4, As, Se, F, organics, (PAH, carcinogens)	Ca, Mg, Zn, Cd, Hg, B, organics (phenols, etc.)	Pb, Cu, Fe
	High TDS waste water	TDS	--	--
	Sour water	Ammonia, phenols	Organics	--
	Retort water	As, Cl, S, organics (POM, carboxylic acids, phenols), reduced S compounds	TDS, organics (amines, etc.)	Carbonates, PO_4, NO_3
	Effluent holding pond	TDS, organics	Traces metals, nutrients	--
	Raw shale	TDS, As, Se, organics, Mo, F	Macroinorganics	Trace metals
	Tankage area	Miscellaneous fuels, oil additives, ammonia, TDS	---	--

TABLE 6.1-1 (cont.)

Source Pollution Ranking	Potential Pollution Source	Potential Pollutant Ranking		
		Highest	Intermediate	Lowest
Intermediate	Miscellaneous process waste streams	TDS, organics, ammonia	Macroinorganics, trace metals	Nutrients
	Stormwater runoff	TDS, organics, As, Se	Na, Ca, SO_4, HCO_3, organics	Zn, Cd, Hg
	Water treatment plant sludges	TDS	Major macroinorganics	Trace metals
	Miscellaneous landfill materials	Sulfides, organics	Sulfides	--
	Sulfur by-products	Sulfides, sulfates	--	--
	Oily waste waters	Organics	Trace metals	--
	Spent filters	Organics, As	Trace metals	--
Lowest	Sewage Sludge	Organics	Nutrients	--
	Mine water	TDS, oil and grease, nitrates, ammonia	Trace metals, organics	Macroinorganics

TABLE 6.1-1 (cont.)

Source Pollution Ranking	Potential Pollution Source	Potential Pollutant Ranking		
		Highest	Intermediate	Lowest
Lowest (cont.)	Sanitary waste water	Organics	Nutrients	Macroinorganics
	Surface disturbance	Calcium and Sodium salts, TDS	Macroinorganics	--
	Miscellaneous process waste streams	TDS, organics, ammonia	Macroinorganics, trace metals	Nutrients

TABLE 6.1-2

POSSIBLE COMPOSITION OF
LEACHATE FROM PROCESSED OIL SHALE

Parameter		Maximum	Minimum
pH		11.8	5.8
Specific Conductivity		34,100	1,600
TDS (a)		17,330	1,330
Calcium	Ca	648	131
Magnesium	Mg	390	0.21
Sodium	Na	10,400	194
Potassium	K	1,460	<0.02
Carbonate (a)	CO_3	0	0
Bicarbonate (a)	HCO_3	100	30.5
Chloride	CL	2,300	60
Sulfate	SO_4	20,000	774
Aluminum	Al	0.81	<0.01
Arsenic	As	0.20	<0.01
Barium	Ba	0.37	0.030
Beryllium	Be	0.013	<0.005
Boron	B	3.18	<0.005
Cadmium (a)	Cd	0.45	<0.07
Chromium	Cr	0.090	<0.001
Copper	Cu	2.44	0.004
Fluoride	F	19.7	0.82
Iron	Fe	1.20	<0.01
Lead	Pb	0.031	<0.005
Manganese	Mn	0.31	<0.01
Nickel	Ni	0.10	<0.01
Nitrate	NO_3	47.0	<0.1
Selenium	Se	0.035	<0.02
Silica	SiO_2	53.6	2.32
Silver	Ag	0.006	<0.001
Strontium	Sr	13.6	1.25
Vanadium	V	0.45	<0.1
Zinc	Zn	3.92	0.03
Molybdenum	Mo	9.45	0.34

All parameters are in mg/l, except for pH in units and specific conductance in micromhos/cm.

Data from Harbert, Berg and McWhorter, 1979 except for those identified by parameter(a), from McKell Van Epps and Richardson, 1979.

The primary source of pollutants on the tracts will be the processed shale pile, which will also constitute a fabricated vadose zone overlying the indigenous vadose zone. Leachate contaminants in the processed shale pile will include an extremely high salt concentration and a high loading of organics. The mobility of salt will be dependent on precipitation and water application for dust control which could remove calcium and magnesium carbonates and gypsum. Some sorption on organics may occur. The mobility of organics will be enhanced by the high TDS, and both contaminants (organics and inorganics) will be leached together. Organic concentrations may decrease through precipitation at higher pH values, through surface reactions, through autooxidation, and through microbial decomposition. Trace metal mobility will be affected by pH, complexing with organics, absorption on organics, precipitation as sulfides, etc. (EPA 1979).

Compounds in processed shale leachate may be diluted by a variety of physical and chemical processes. However, because of the initially high concentrations of the major inorganic constituents, the overall salinity level will remain high.

Plant Site

Construction of the processing plant, the wastewater holding pond, the mine facilities and storage of raw shale are the main activities that will effect this drainage. The proposed effluent holding pond draining the process area watershed, raw shale storage, and the tankage area are the primary sources of pollution potential. The highest ranking pollutants include dissolved salts, organics, selenium, arsenic, molybdenum, fluoride and tankage contents (fuels, oil additives, and ammonia).

In addition, excavation of a mine shaft and underground mine could induce minor losses in ground water storage in the Birds Nest Aquifer located above the mining zone. Should this occur, minor decreases

in baseflow to Evacuation Creek could result (during baseline monitoring, Evacuation Creek received about 0.5 cubic feet per second (cfs) of discharge from the Birds Nest Aquifer during the baseflow period).

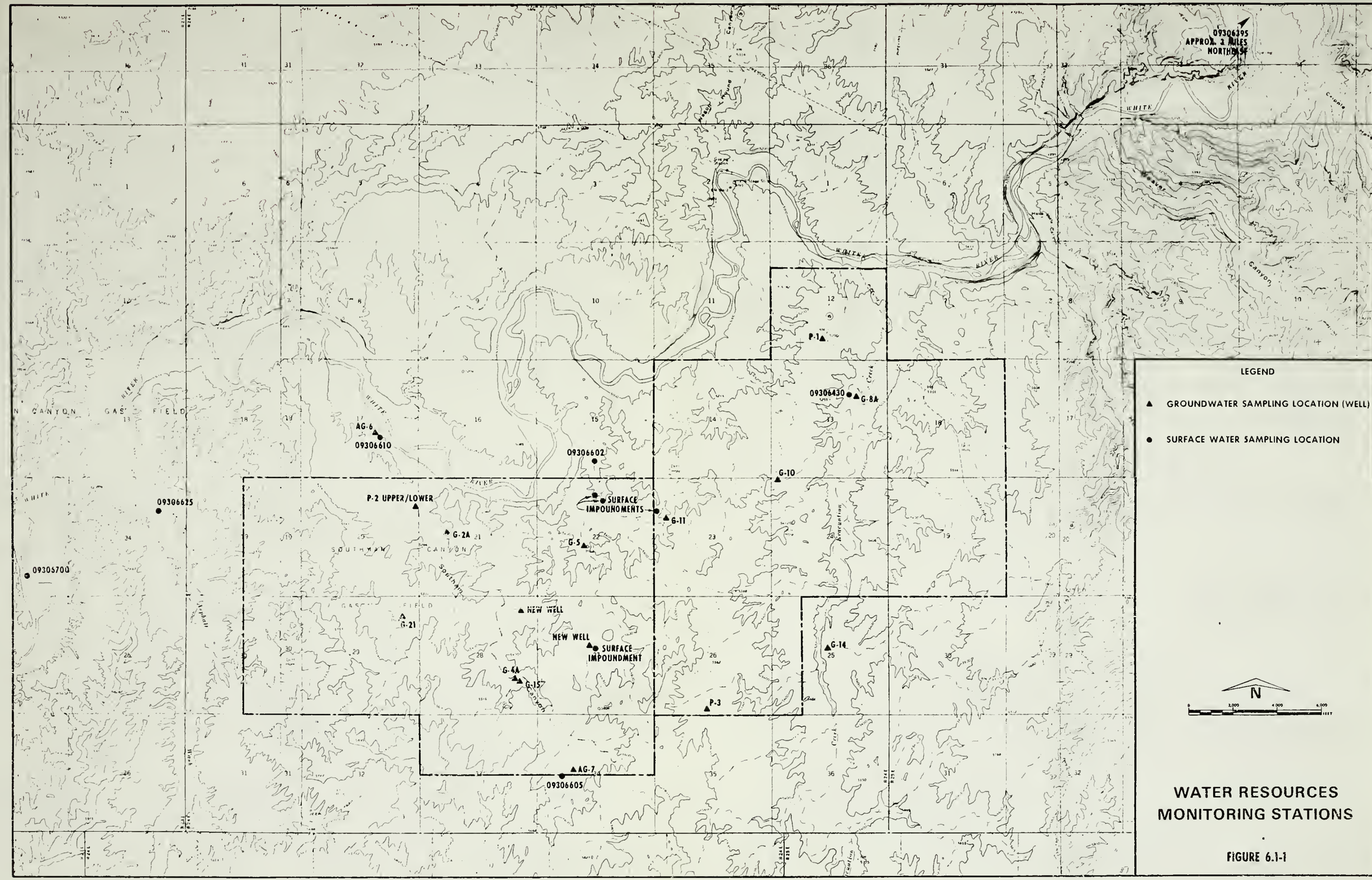
Evacuation Creek

The Evacuation Creek drainage basin constitutes more than 60% of the drainage area between the White River at the state line and the White River below Asphalt Wash. The streamflow contributed by Evacuation Creek to the White River, therefore, provides a dominant local effect on the White River.

The only major activity in this basin is the construction of access roads. Thus, soil disturbance may temporarily increase the dissolution of mineral salts and promote soil erosion. Therefore, the highest priority pollutants in Evacuation Creek will be TDS and suspended sediment concentration. Some minor increase in surface runoff can be expected from areas affected by construction, but this would not significantly affect the surface flow regime of Evacuation Creek. It is also possible that oil and gas exploration in the upper reaches of Evacuation Creek could contribute contaminants which would be detected during monitoring in Evacuation Creek and the White River.

White River

Chemical and physical perturbations created from on-site project activities can potentially discharge materials into the White River under unplanned conditions (i.e., during floods and following accidental spills and leaks). Therefore, the monitoring program on the White River will incorporate all of the high priority pollutants possible from other drainages.



LEGEND

▲ GROUNDWATER SAMPLING LOCATION (WELL)

● SURFACE WATER SAMPLING LOCATION

WATER RESOURCES MONITORING STATIONS

FIGURE 6.1-1

Asphalt Wash

Only habitat enhancement activities are planned in Asphalt Wash during project development. This dry wash drainage will be used as a control to delineate long-term natural variations which may occur in the project vicinity.

6.1.2 Parameters to be Studied

The following paragraphs describe the various parameters selected for monitoring during project development and operation. Each parameter selected for monitoring has been identified as falling under one or more of the following:

- o is included in the state of Utah and/or federal water quality standards applicable to the White River and its tributaries;
- o are indicators of a pollution source;
- o could reach deleterious levels within project wastewater or leachate;
- o are required for interpretive analysis of the water quality and/or aquatic ecology monitoring results.

The parameters included in the monitoring program will provide indications of project-related impacts, should any occur, from the raw and processed shale storage and disposal piles, processed waste effluents and construction and shale processing activities. In addition, because some impacts are unique to surface or ground water systems, the parameters used in monitoring for these effects may differ.

Surface Water

Operational Parameters

Continuously collected data on stage, specific conductance, and temperature will be recorded at all stream gauging locations (Figure 6.1-1). Data from a continuous stage recorder are needed to determine daily discharge and aid in the engineering design of retention dams, culverts, roads, ditches, levees and similar structures. Continuous monitoring of specific conductance will detect accidental spills which may cause intensive short-term impact.

Periodic collection of sediment is included in the monitoring program because increases in surface erosion and water-transported sediment loads may result from construction-related soil disturbances. Such disturbances would result in increases in sediment load carried by streams. Continuous monitoring of temperature is essential for ecological studies, including evaluating biotic thermal tolerances.

Operational water quality parameters were selected because they are the major organic and inorganic constituents that characterize the natural surface waters on the tracts. These constituents are also essential in detecting priority pollutants associated with oil shale leachate (Tables 6.1-1 and 6.1-2). The operational water quality parameters in Table 6.1-3 will be analyzed on a quarterly basis because of their importance in early detection of project contamination.

Potential Parameters

Potential water quality parameters (Table 6.1-3) were selected from the list of intermediate and low prority pollutants (Tables 6.1-1 and 6.1-2). Also, several parameters were selected because they are required by state and/or federal regulations (i.e., NPDES). These constituents, normally found in low concentrations, but possibly

TABLE 6.1-3

MONITORING PARAMETERS FOR LABORATORY ANALYSIS OF
SURFACE AND GROUND WATER QUALITY FOR TRACTS U-a AND U-b

Operational Parameters	Potential Parameters	
Determined Quarterly	Determined Semi-Annually Only	
Alkalinity as $CaCO_3$, total	Aluminum, dissolved	Oil and grease, total
Bicarbonate	Ammonia an N, dissolved	Organic halogens, total(d)(e)
Boron, dissolved	Arsenic, dissolved	Organic nitrogen as N, total
Calcium, dissolved	Barium, dissolved	Orthophosphorus as P, dissolved
Carbonate, dissolved	Beryllium, dissolved	Phenols, total
Chloride, dissolved	Biochemical oxygen demand(d)	Phosphorus as P, total
Fluoride, dissolved	Cadmium, dissolved	Selenium, dissolved
Hardness as $CaCO_3$, total	Chemical oxygen demand	Silver, dissolved
Magnesium, dissolved	Chromium, dissolved	Strontium, dissolved
Nitrate as N, dissolved	Chlorine, residual	Sulfide, total
Nitrite as N, dissolved	Coliform, fecal(d)	Thiocyanate, total
Organic carbon, dissolved(a)	Color	Turbidity(d)
pH	Copper, dissolved	Vanadium, dissolved
Potassium, dissolved	Cyanide, total	Zinc, dissolved
Silica as SiO_2, dissolved	Gross alpha(b)	
Sodium, dissolved	Gross beta(c)	
Sodium adsorption ratio	Iron, dissolved	
Sodium percent	Lead , dissolved	
Solids, dissolved (calculated)	Manganese, dissolved	
Solids, dissolved (residue at 180°C)	Mercury, dissolved	
Solids, suspended(d)	Molybdenum, dissolved	
Specific conductance	Nickel, dissolved	
Sulfate, dissolved		

(a) If the dissolved organic carbon (DOC) value exceeds the baseline mean by four times or if significant trends in DOC are identified, the laboratory will analyze for DOC fractionation into six parts (the acid, base, and neutral fractions of the hydrophobics and hydrophilics). During the first year prior to operations, DOC fractionation will be determined quarterly for selected surface water monitoring locations and once for selected ground water sites.
(b) If gross alpha activity is greater than 4 picoCuries/liter, the laboratory will analyze for radium 226 and natural uranium.
(c) If gross beta activity is greater than 100 picoCuries/liter, the laboratory will analyze for strontium 90 and cesium 137.
(d) To be determined for surface waters only.
(e) Sampled one time only for surface water, approximately one year prior to operations.

indicative of project-related impacts, will be analyzed on a semi-annual basis. After the water found in the on-tract impoundments or lysimeters has been characterized, potential parameters will be reclassified as either operational or contingency parameters. For instance, those parameters measured at potentially harmful levels will be reclassified as operational parameters. Other parameters will be deemed contingency parameters and included in analyses following accidental discharges or situations where contingency sampling is initiated.

Contingency Parameters

Presently, no parameters are included in the contingency category. Contingency parameters will be delineated during the operational monitoring program.

Ground Water

Operational Parameters

Continuous and quarterly static water level measurements will be collected at alluvial and deep ground water wells. These measurements will assist in determining if changes in ground water storage are occurring. Parameters included in the ground water quality monitoring program (Table 6.1-3) are reflective of natural water quality conditions, as well as indicative of the possible high priority pollutants that might reach ground water sources.

Potential Parameters

Presently, only limited data are available which specifically delineate parameters and concentrations expected from process waters and oil shale leachate. The potential parameters listed (Table 6.1-3) are on a trial basis and will be evaluated annually to determine their

usefulness in a monitoring program. The parameters were selected from the list of intermediate and low priority pollutants expected in oil shale leachate and to fulfill state and/or federal regulations.

Contingency Parameters

There are presently no designated contingency parameters. Potential parameters which are found to be of limited value will be entered into this category as the monitoring program becomes implemented.

6.1.3 Sampling Locations and Schedule

The locations and frequency of sampling have been chosen to detect unplanned point discharges as well as to monitor effluents derived from non-point discharges. For example, environmental perturbations resulting from accidental release of contaminated water would not normally be detected by periodic sampling. However, early detection of a change in critical parameters (such as conductivity or sediment concentration) can be accomplished by a continuous monitoring program. If such an accident occurs, intensive monitoring and/or sampling would isolate the contaminant and determine its source, movement and concentration. All monitoring sites will utilize existing surface water gauging stations established during the baseline period.

Surface Water

The surface water monitoring program is listed in Table 6.1-4.

Southam Canyon

Stage, temperature, and specific conductance will be continuously recorded at the mouth of Southam Canyon Wash (09306610) (Figure 6.1-1). Instantaneous discharge measurements at the upper Southam Canyon Wash station (09306605) will be made whenever flow occurs, if possible. A

TABLE 6.1-4

SURFACE WATER MONITORING STATIONS

U.S. Geological Survey Station Number	Station Location	Parameters Monitored	Frequency of Collection
09306395	White River near Colorado-Utah State Line, Utah	Q	Continuous
		SS	Periodic
		Ec	Continuous
		T	Continuous
		WQ	Quarterly
09306430	Evacuation Creek near Watson, Utah (near mouth of creek)	Q	Continuous
		SS	Periodic
		Ec	Continuous
		T	Continuous
		WQ	Quarterly
09306602	Unnamed wash downstream of proposed plant site	Q	Continuous
		SS	Opportunistic
		Ec	Continuous
		T	Continuous
		WQ	Opportunistic
09306605	Southam Canyon Wash near Watson, Utah	Q	Opportunistic
		SS	Opportunistic
		Wq	Opportunistic
09306610	Southam Canyon Wash at mouth, near Watson, Utah	Q	Continuous
		SS	Opportunistic
		Ec	Continuous
		T	Continuous
		WQ	Opportunistic
09306625	Asphalt Wash near mouth, near Watson, Utah	Q	Continuous
		SS	Opportunistic
		WQ	Opportunistic
09306700	White River below Asphalt Wash, near Watson, Utah	Q	Continuous
		SS	Periodic
		Ec	Continuous
		T	Continuous
		WQ	Quarterly

Notes: Q = discharge (gauge height)
SS = suspended sediment
Ec = Specific conductance
T = Temperature
WQ = Water quality samples

crest stage gauge and staff gauge will be present at this station to record peak flows and define a rating curve.

Because Southam Canyon is a dry wash, suspended sediment and water quality will be sampled at both stations during all storms, if possible. The field water quality measurements of temperature, pH, specific conductance, and dissolved oxygen will be made. All water samples will be analyzed for the operational and potential list of parameters shown in Table 6.1-3. The monitoring station at the lower Southam Canyon site will detect any unintended discharge of water from the retention dam. This station will be moved upstream when the White River Reservoir is completed to avoid backwater effects.

Plant Site Wash

The monitoring station in Plant Site Wash (09306602) will detect any unintended release of wastewater effluents generated by the processing plant. Stage, temperature, and specific conductance will be continuously recorded.

Because this stream is ephemeral, the schedule and scope of water quality sampling for station 09306602 below the plant site will be the same as for the Southam Canyon stations. Water and sediment will be sampled during runoff events, if possible.

On-Tract Impoundments

The volume of water in the project impoundments will be monitored by measuring the depth of water, as shown by a permanently mounted staff gauge. Water level recorder may be used for impoundments that will be used on a long-term basis. The depth of sediment in the impoundment will also be monitored so that the actual water volume and capacity of the impoundment can be determined.

At the retention dam below the Phase I processed shale pile in Southam Canyon (Figure 6.1-1), water will be sampled immediately following runoff events. All samples will be analyzed for operational and potential list of parameters shown in Table 6.1-3. Sampling will continue until the final list of operational parameters is formulated. Field measurements of water quality will also be made during sample collection. The primary constituents identified in the leachate will become indicators of project contamination in the event of a spill or leak in Southam Canyon.

At the wastewater holding basin at the plant site, water samples will be collected and field measurements of water quality will be made quarterly if possible. All water samples will be analyzed for the list of parameters shown in Table 6.1-3 until the final list of operational parameters is formulated. The primary constituents identified in the wastewater will become indicators of project contamination in the event of a spill or leak. All water samples will be analyzed for a six-part fractionation of dissolved organic carbon to determine their origin.

Evacuation Creek

Stage, temperature, and specific conductance will be continuously recorded by WRSOC at station 09306430 near the mouth of Evacuation Creek (Figure 6.1-1).

Suspended sediment samples will be collected at this station at frequencies determined by streamflow conditions. Sample collection will be most intense during the snowmelt runoff period and during and following runoff from intense thunderstorms. The number of samples collected will vary from one to several per day depending on the degree of streamflow variation. During the baseflow period, samples will be collected weekly. All suspended sediment samples will be collected manually.

The schedule and scope of field and laboratory water quality analyses for the Evacuation Creek stations is the same as for the White River stations, except that the quarterly sampling is expected to occur in January, April, July, and September, with the semi-annual sampling in April and September.

Because sedimentation is the significant potential impact in Evacuation Creek, statistical comparisons with the baseline record will be employed to detect project-related changes.

White River

The two stations on the White River (Figure 6.1-1) are located upstream (09306395) and downstream (09306700) from the tracts. These sites monitor regional surface water characteristics. The downstream station is unlikely to be effected by project activities because containment of all runoff from the tracts is required. However, road construction and development activities could cause increased sedimentation in the White River via Evacuation Creek. In addition, an accidental discharge could affect water quality of the White River.

Continuous records of stage, temperature, and conductivity will continue to be collected at both stations. The U.S. Geological Survey currently operates the upstream station on the White River, whereas WRSOC operates the downstream station. Monitoring at an upstream station will be required as a control in the monitoring program and as part of the lease requirements. The sediment and water quality data collection at both stations will be coordinated.

Periodic suspended sediment samples will be collected at the downstream site at frequencies dependent upon the streamflow conditions. During peak flows sediment samples will be collected daily. During baseflow periods, samples will be collected less frequently, ranging from twice weekly during the summer to once a week during the winter. Sampling

frequency will be such that the sediment curve is well defined for all flow events. Discharge measurements will be taken with each sediment sampling trip to help define the sediment rating curve.

The water quality samples will be collected quarterly at both of the White River stations for laboratory analysis of the parameters listed in Table 6.1-3. Additional parameters will be analyzed semi-annually. The quarterly sampling is expected to occur in March, June, September, and December. The semi-annual sampling will occur during peak runoff from snowmelt (June) and during the late summer baseflow period (September). These semi-annual sampling periods were selected because they represent the seasonal extremes in natural water quality concentrations. Peak flows commonly transport low concentrations of dissolved materials, whereas baseflows often transport the highest annual concentrations of dissolved constituents. Several parameters, including streamflow, water temperature, specific conductance, pH and dissolved oxygen, will be measured in the field at the time of sample collection.

Asphalt Wash

The U.S. Geological Survey currently operates the continuous surface water station on Asphalt Wash (Figure 6.1-1). Although Asphalt Wash is an ephemeral stream, the schedule and scope of opportunistic water quality monitoring for station 09306625 will be compatible with the data collection needs of WRSOC. Because the hydrologic characteristics of dry washes are similar, the USGS data collected at this site will be utilized as a control group in the statistical analysis with Plant Site Wash.

Ground Water

The oil shale tracts contain two ground water systems of concern, the alluvial groundwater and the Birds Nest Zone (commonly referred to

as the Birds Nest Aquifer). Initially, contaminant movement into these ground water systems will most probably occur in the indigenous vadose zone beneath the processed shale pile and/or process area wastewater basins. The indigenous vadose zone for tracts Ua and Ub is defined as the region extending from the land surface to the interface between the confining Green River Formation mudstones and the Birds Nest Zone. This zone consists of about 400 to 600 vertical feet of Uinta sandstones and Green River mudstones extending to the Birds Nest Zone and of about 20 feet of alluvial sediments (alluvial ground water system).

The thickness of the vadose zone beneath the spent shale disposal area will be modified during deposition of shale wastes, i.e. the vadose zone in this area will be growing as layer upon layer of spent shale is stacked above the surface of the Uinta Formation. The finished surface of the man-made plus indigenous vadose zone will consist of a temporarily sealed layer and soil trenches for vegetation. The average total thickness of the vadose zone will be about 850 feet. (Average depth of shale pile is about 200 feet.)

The hydraulic properties of the vadose zone beneath the process area and Southam Canyon retention dam are essentially the same. Water and contaminant movement in the Uinta sandstones will move primarily through cracks, fissures, and along bedding planes. Because of the constrictive nature of such cracks and openings, flow rates will be very slow. In addition, field observations indicate that cracks tend to pinch out within claystone beds in the Uinta Formation and where the Uinta sandstones merge with underlying Green River mudstones. The latter deposits serve as the overlying confining beds for the Birds Nest Zone. Water and pollutants seeping within the vadose zone must form saturated conditions above the confining bed with hydraulic head higher in the saturated area than in the Birds Nest Zone before movement into the aquifer will occur. (The Birds Nest Zone is saturated and has several hundred feet of artesian head under the northern part of the Tract Ua).

Because of the numerous claystone layers within the Uinta Formation and the Green River Formation, the contaminated water moving through the vadose zone may form saturated perching layers. The regional structure would cause the water to flow down dip to the northwest. If the pollutants flow along clay beds which are deep in the section, they will pass beneath the White River, and eventually dissipate within the Uinta Formation. If the perching beds are higher in elevation, the pollutants will flow into the alluvium of the White River valley and thus eventually into the river. The presence of evaporite deposits on sheltered outcrops of the claystone beds of the Uinta Formation indicates that, at the present time, very small amounts of moisture infiltrates and moves along these beds.

The proposed ground water monitoring program has centralized monitoring in the alluvium near disturbed areas and the processed shale pile to characterize quantity and quality of leachate. The ground water monitoring program will include sampling stations that will be used on a contingency basis.

Southam Canyon

The precise location of the monitoring wells and sampling schedules will depend on the development schedule and location of the processed disposal pile in Southam Canyon. Existing alluvial and deep ground water wells will be utilized as much as possible. New alluvial and Uinta Formation wells will be needed to replace existing wells at the toe of the processed shale pile advance during Phases II and III. The monitoring well locations and date of operation are listed in Table 6.1-5 for Southam Canyon. The parameters to be monitored are discussed below.

Continuous water levels will be recorded at deep wells P-2 lower and P-2 upper. Static water levels will be recorded for alluvial wells G-2A, G-4A, AG-6, AG-7 and two new wells to be installed immediately

TABLE 6.1-5

EXISTING WELLS TO BE USED FOR
MONITORING GROUND WATER QUALITY

Area	Well Number	Geologic Unit Monitored	Water Level Monitoring Frequency	Water Quality Monitoring Frequency	Monitoring Begins One Year Prior To
Southam Canyon	G-2A	Alluvium	Quarterly	Contingency	--
	G-4A	Alluvium	Quarterly	Contingency	--
	AG-6	Alluvium	Quarterly	Semi-Annual/Quarterly	Process Shale Disposal
	AG-7	Alluvium	Quarterly	Contingency	
	New wells (2)	Alluvium, Uinta Formation	Quarterly	Semi-Annual/Quarterly	Process Shale Disposal
	P-2 upper	Uinta Formation	Continuous	Annually	Mine Excavation
	P-2 lower	Birds Nest Aquifer	Continuous	Annually	Mine Excavation
	G-15	Birds Nest Aquifer	Quarterly	Contingency	--
	G-21	Birds Nest Aquifer	Quarterly	Contingency	--
Plant Site Wash	New wells (4)	Alluvium, Uinta Formation	Quarterly	Semi-Annual/Quarterly	Commencement of Retorting
	G-5	Birds Nest Aquifer	Quarterly	Annually	Mine Excavation
	G-11	Birds Nest Aquifer	Quarterly	Annually	Mine Excavation
Evacuation Creek	P-1	Birds Nest Aquifer	Continuous	Contingency	--
	P-3	Birds Nest Aquifer	Continuous	Contingency	--
	G-8A	Birds Nest Aquifer	Quarterly	Contingency	--
	G-10	Birds Nest Aquifer	Quarterly	Contingency	--
	G-14	Birds Nest Aquifer	Quarterly	Contingency	--

No monitoring wells are anticipated along Asphalt Wash or the White River.

below the surface impoundment in Southam Canyon (see Figure 6.1-1). Alluvial well AG-6 will be relocated up-gradient from the backwater from the White River dam prior to inundation. Bedrock aquifer wells G-15 and G-21 will also be monitored for static water levels.

Static water level measurements will be monitored quarterly for alluvial wells and semi-annually for bedrock aquifer wells. Anticipated monitoring dates for a semi-annual program are during June and December. Collection dates for quarterly monitoring are during March, June, September and December to coincide with surface water monitoring.

Alluvial wells AG-6 and the two new wells will initially be sampled semi-annually (June and December) for water quality. When the Phase I processed shale disposal commences the frequency of sampling will be increased to quarterly (March, June, September, December). Bedrock aquifer wells G-15, G-21, P-2 upper, and P-2 lower will be sampled annually (during May or June) throughout project operations. More frequent monitoring may be performed if it is apparent from data analysis that water quality and/or ground water storage is being affected by project development (see contingency monitoring).

Prior to any disposal of processed shale, two lysimeters will be established at the base of the pile to capture leachate that may percolate through the pile. As the shale pile increases in height, salinity sensors, high pressure lysimeters and tensiometers will be installed at two locations in the central portion of the pile. These will be installed to a depth of less than 50 feet below the finished surface of the pile. Water will be sampled quarterly (during the months above) from the lysimeters and readings will be taken from the tensiometer (soil moisture tension) and salinity sensor (salinity). The purpose of these devices is to characterize the quantity and quality of any leachate generated during project development. This will assist in defining:

- o the rate of leachate movement within the processed shale pile and

- o help define the quality of leachate generated during the course of the project.

Plant Site Wash

Water within alluvium and the Uinta Formation adjacent to specific process-related facilities will be monitored. This will involve the installation of alluvial wells or lysimeters, tensiometers and salinity sensors at the following locations:

- o Upslope of the upper embankment for the shale fines storage area.

- o Downslope of the lower embankment for the shale fines storage area.

- o Upslope of the wastewater holding basin and downslope of the tankage area.

- o Downslope of the wastewater holding basin (two wells).

- o Immediately downslope of the raw shale storage area.

Static water levels and water quality samples will be collected at bedrock aquifer wells G-5 and G-11. The proposed schedule will include quarterly water levels (March, June, September, December) and annual (May or June) water sample collections to coincide with surface water sampling.

The alluvial wells or lysimeters will initially be sampled for level and water quality semi-annually (June and December). When the Phase I

raw shale stockpiling or processing begins, the frequency of sampling will be increased to quarterly (March, June, September, December). The bedrock aquifer wells will be sampled annually (during May or June) throughout project operations. Water levels will be taken on a quarterly basis. All tensiometers and salinity sensors will be recorded on a quarterly schedule (March, June, September and December).

Presently, the Plant Site Wash is believed to contain very little or no water in the alluvium. Thus, modifications to this program may be required during project operations.

Evacuation Creek

Ground water monitoring in the Evacuation Creek drainage will consist of monitoring water level fluctuations in the Birds Nest Zone. It is anticipated that no impacts will occur to the alluvial ground water system in Evacuation Creek. The wells monitored will include P-1, P-3, G-8A, G-10 and G-14. Wells P-1 and P-3 will have continuous water level recorders. Wells G-8A, G-10 and G-14 will have static water level measurements recorded on a quarterly basis.

The reason for monitoring ground water levels in this area is to identify changes in ground water storage in the Birds Nest Zone which could be attributed to shaft excavation and potential mine dewatering. In addition, loss of water stored in the Birds Nest Zone may cause changes in the baseflow of Evacuation Creek (which is known to receive water from the Birds Nest Aquifer).

Asphalt Wash and White River

No anticipated ground water monitoring is proposed for Asphalt Wash or the White River.

6.1.4 Fulfillment of Objectives

The water resources program will identify perturbations caused by development, by using statistical comparisons of baseline data to that obtained during operational monitoring. In addition, the program will evaluate the effectiveness of mitigation measures during Phase I activities and determine their suitability for a large-scale development (Phases II and III).

The objectives of the program will be fulfilled by:

- The use and location of control and treatment stations.
- The combination of monitoring certain parameters continuously, periodically and opportunistically.
- Program flexibility which may include relocation of monitoring stations and/or altering monitoring schedules so that project-related perturbations may be rapidly detected.

6.2 Methods

6.2.1 Methods of Data Collection

U.S. Geological Survey techniques from their series of publications, "Techniques of Water Resources Investigations (TWRI)" will be used in the water monitoring program (Table 6.2-1). Additional techniques are also employed as outlined in "Standard Methods for the Examination of Water and Wastewater," such as field measurements of water quality parameters. Laboratory procedures are performed in accordance with the Federal Code of Regulations, Chapter 1, Part 136, "Guidelines establishing test procedures for the analysis of pollutants." Reporting of significant figures and many basin and stream characteristics are calculated following guidelines of "National Handbook of Recommended Methods for Water-Data Acquisition."

TABLE 6.2-1

STANDARD METHODOLOGY USED IN WATER RESOURCES MONITORING

Task	Reference (Author)
Stream discharge measurements	TWRI (Buchanan and Somers, 1969)
Maintenance of current meters	TWRI (Smoot and Novak, 1968)
Collection of suspended sediment	TWRI (Guy and Norman, 1973)
Measurement of temperature	TWRI (Stevens, Ficke, and Smoot, 1975)
Measurement of stage	TWRI (Buchanan and Somers, 1968)
Collection of water quality samples	TWRI (Brown, Skougstad, and Fishman, 1970)
Groundwater sampling techniques	TWRI (Wood, 1976)
Measurement of ground water levels	TWRI (Garber and Koopman, 1968)
Field measurements of water quality parameters	Standard Methods (15th Ed.) AWWA
Lab procedures for water quality analyses	Code of Federal Regulations Title 40, Part 136
Basin and stream characteristics	Recommended methods for water data acquisition (National Handbook of Recommended Methods of Water-Data Acquisition) (U.S. Geological Survey)
Data reporting	Recommended methods for water data acquisition (National Handbook of Recommended Methods of Water-Data Acquisition) (U.S. Geological Survey)

6.2.2 Materials Needed

The water resources monitoring program requires specialized instruments and equipment. Table 6.2-2 summarizes the equipment needs for performing the monitoring plan. Additional "state-of-the-art" instrumentation will be used for specialized monitoring, as needed.

6.3 Quality Assurance/Quality Control Procedures

6.3.1 Quality Assurance (QA) Program Design

The purpose of the quality assurance/quality control program for the water resources program will be to guarantee the accuracy, precision, completeness, representativeness and comparability of sampling data. The program will allow comparison of data and results obtained throughout the WRSOC monitoring program disciplines.

Methods employed will be those specified by the USGS and the EPA.

Quality Control (QC) Program Design

The computer software and data management system designed for the project are intended to ensure consistency and maintain an accurate record of data collected during the monitoring program. Data collected during monitoring activities will be maintained by (1) checking all calculations, (2) utilizing computer coding forms for all data entry with checks made against the original and output data, and (3) data entry and filing procedures for all data collected.

Technical and Quality Assurance Reviews. Technical reviews will involve quality assurance personnel in regular investigations of:

- The establishment of preventive maintenance procedures for equipment used on the project.

TABLE 6.2-2

WATER RESOURCES EQUIPMENT REQUIREMENTS

Parameter	Required Equipment
Surface Water	
Continuous stage measurement	Stilling well or Bubble gauge Water level recorder Staff gauge
Continuous temperature	Special water quality recorder and probe
Continuous conductivity	Special water quality recorder and probe
Suspended sediment	DH-48, D-49
Water quality--field measurements	pH meter, digital thermometer conductivity meter, dissolved oxygen meter
Water quality--sampling	DH-48 (teflon nozzle and silicon gasket), D-49, sample splitter, barrel filter, DOC filter apparatus
Instantaneous discharge	Price AA current meter Pygmy current meter Top-setting wading rod Flume Cable car and accessories
Ground Water	
Continuous water level	Water level recorder
Static water level	M-scope/steel tape
Water quality--field measurements	Same as surface water
Water quality--sampling	Bailer (teflon or plastic) Submersible pump (deep aquifers) Barrel filter DOC filter apparatus

TABLE 6.2-2 (cont.)

Parameter	Required Equipment
Vadose Zone	
Salinity	Salinity sensor and probe
Soil moisture	Tensiometer and probe
Water quality--field and lab	Lysimeter or leachate collector (in-place); other equipment same as surface water requirements

- A calibration/standardization record for instruments regularly used in project activities including a compilation of standarization procedures.

- A history file on each instrument needing calibration/standardization containing a log showing instrument accuracy at receipt, adjustments made, instrument accuracy after adjustments, calibration/standardization date, calibration/standardization due dates, instrument identification, identification of standard(s) used, signature of person performing calibration/standardization, and so forth.

Technical reviews will also involve the review of established written procedures for collection, reduction, and analysis of data. Such reviews will include the inspection of all checklists, field forms, and data sheets used for the water resources monitoring program. Such reviews will stress correct use of forms, continuity of performance, and the continued use of quality control procedures. Samples of these forms follow the QC discussion.

Document control involves the coordination and control of project records to ensure the accuracy, retrievability and traceabilty of records. This includes all figures, tables, original graphics, calculations and text material used in, or as reference material for technical reports.

Audits will involve the periodic scheduled surveillance of project staff, laboratory testing activities and project activities to ensure that work is performed according to established procedures and applicable regulatory guides and standards. These audits will ensure that sufficient backup information and reference material is obtained and is traceable to technically acceptable sources. The results of these audits will be presented in periodic audit reports.

Field Sampling. The quality control procedures to be included as part of field monitoring and sample collection include the following:

- o Instrument calibration (e.g. use of proper standard, proper number of standards and appropriate frequency of recalibration).

- o Use of appropriate sample collection procedures.
  - appropriate bottle type (e.g., clear glass, dark glass, sterile bottles, polyethylene).
  - measurement of conductivity, pH, temperature during bailing or pumping of wells to obtain representative samples
  - proper field processing and preservation methods (e.g. filtration, addition of chemical preservatives and cooling)
  - proper packing and shipping procedures when sending samples to the analytical laboratory

- o Proper data management techniques for data collected in the field and received from the laboratory.

Laboratory Techniques. Reliable and accurate techniques for the laboratory analysis of water samples has been well documented. The Federal Water Pollution Control Act established guidelines for analyzing pollutants in Title 40, Part 136, "Guidelines Establishing Test Procedures for the Analysis of Pollutants". In addition, the following manuals are used where the guidelines have not specified a technique:

- o Standard Methods for the Examination of Water and Wastewater, 15th Edition, USPHA, AWWA, WPCF.

- o Methods for Determination of Inorganic Substances in Water and Fluvial Sediment, USGS, Book 3, Chapter A1.

- o Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020.

- o 1980 American Book of ASTM Standards Part 31 Water, American Society of Testing and Materials.

In addition to employing the well-established and reproducible methodologies specified by the aforementioned manuals, the laboratory will be required to employ strict quality assurance/quality control procedures.

The following specifications/procedures will be required of any subconsulting laboratory performing water quality analyses on samples collected for the duration of the project.

1. Chemical analytical methods used should be in accordance with the references listed in CFR Title 40 Part 136.

2. The laboratory shall routinely provide a listing of minimum quantification limits/detection limits for each parameter whose analysis is required for the project during each data reporting period.

3. The laboratory shall routinely provide trace metal concentration data of the distilled/de-ionized water that is to be used as diluent in the trace metal analyses.

4. The following tasks shall be performed by the laboratory for quality assurance purposes:

   a. The laboratory shall analyze approximately 10% of all samples in duplicate. In addition, at least one sample in each sample set forwarded to the laboratory shall be analyzed in duplicate. Precision for the parameters shall be at least equivalent to the precision data reported in the referenced methods at the concentrations determined.

   b. Precision shall be measured as the percent difference between the two values obtained. The average of the values shall be used to base the percentage difference. Thus,

$$\text{Percent Difference} = \frac{(V_1 - V_2) \times 100}{\frac{V_1 + V_2}{2}}$$

Where V_1 and V_2 are the experimentally determined concentrations.

c. The laboratory shall show evidence of participation in EPA cross-checking programs involving analyses of selected reference samples.

d. The laboratory shall provide quality control data quarterly. This will involve the presentation of the results of Items 3, 4a, 4b, and 4c as well as the results of internal laboratory spiked samples.

5. The laboratory shall provide proper and clean sampling bottles (in adequate numbers) which are to be sent to the primary study area in clean, Coleman-type ice chests. In addition, sample bottle key codes will accompany all shipments and will provide the following information: bottle code numbers, type and size of the sample bottle, preservative, and the parameters to be analyzed in each sample bottle.

6. The laboratory shall provide a color-coded array of labels for each sample bottle containing a preservative.

7. The laboratory shall provide blank water proof labels which are to be placed on the sample bottles prior to shipping to the project area. The labels should contain the following information.

Sample Matrix

Station: _____ Time: _____
Date: _____ Witnessed By: _____
Collected By: _____ Non-filtered: _____
Filtered: _____
Preservative: _____

8. The laboratory shall arrange for sample pick-up at local airport or bus station, following notification of sample arrival by WRSOC.

9. Should a particular parameter be below its lower limit of detection (LLD), the working laboratory lower limit of detection value should be noted for each parameter for each sample period.

10. All parameters being analyzed for will be listed in their entirety along with the phase being analyzed (i.e. dissolved, total, suspended).

11. Where applicable the reference is specific for each parameter. Any method alteration or deviation, for improving the L.L.D. or to circumvent matrix interferences, shall not be initiated by the laboratory prior to notification to WRSOC and the receipt of WRSOC authorization to proceed with any modified testing.

FIELD INSTRUMENT CALIBRATION RECORD

PROJECT _____

INSTRUMENT MAKE AND TYPE _____ MODEL NUMBER _____

SERIAL NUMBER _____ INSTRUMENT PURCHASE DATE _____ PROBE PURCHASE DATE _____

COMMENTS _____

PROBE TYPE	STANDARD SOLUTION PURCHASE DATE	VALUE OF STANDARD SOLUTION	READING BEFORE CALIBRATION	READING AFTER RECHARGING SENSOR	READING AFTER CALIBRATION	CALIBRATED BY	CALIBRATION DATE	REMARKS

SEDIMENT DISCHARGE SUMMARY

LISTED BY _____

CHECKED BY _____

STATION NUMBER _____ STREAM _____

PROJECT _____ WATER YEAR _____

DATE	PARTY	TIME	TYPE OF SAMPLE	CONCENTRATION MG/L	CHART GAGE HEIGHT (FEET)	SHIFT	WATER DISCHARGE (CFS)	SEDIMENT * DISCHARGE TONS/DAY	REMARKS

* COMPUTED INSTANTANEOUS VALUE

VTN CONSOLIDATED, INC.
Environmental Sciences Division

DISCHARGE MEASUREMENT NOTES

Meas. No. _____

Comp. by _____

Checked by _____

Station No. _____ Client _____ Project No. _____

Station Name _____

Date _____ 19 _____ Party _____

Width _____ Area _____ Vel. _____ G.H. _____ Disch. _____

Method _____ No. secs. _____ G.H. change _____ in _____ hrs.

Air Temp. _____ C _____

Water Temp. _____ C _____

Record removed _____ Intake flushed _____

Control _____

_____

G.H. of zero flow _____ ft.

Wading, cable, ice, boat, upstr., downstr., side bridge _____ feet, mile, above, below gage, and _____

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions:

Cross section _____

Flow _____ Weather _____

Samples collected _____

Remarks _____

_____

_____

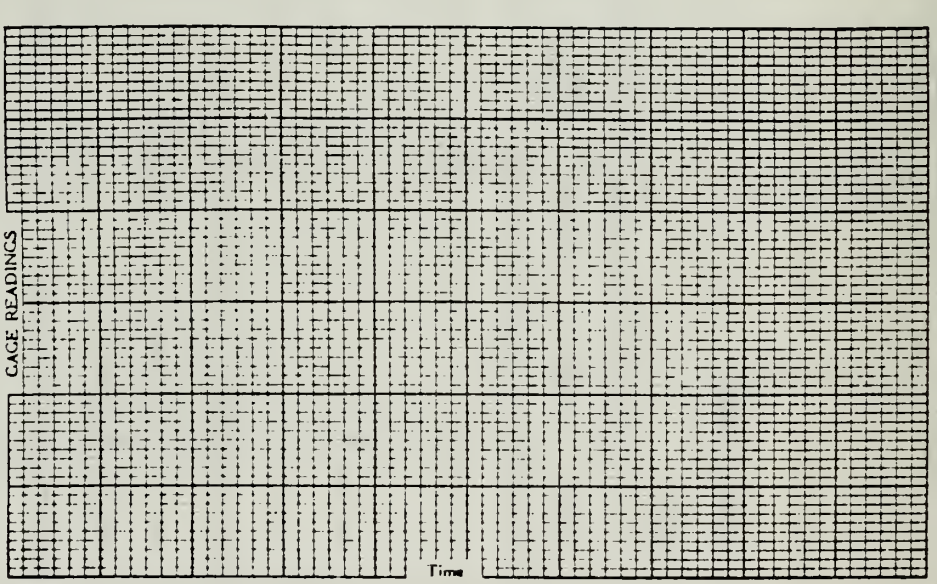
Meas. plots _____ % diff. from _____ rating

Meter No. _____ Meter Type _____

Date rated _____

Spin before meas. _____ after _____

STAFF GAGE READINGS				
Time		Recorder	Inside	Outside
Weighted M G H				
G.H. correction				
Correct M G H				



RIVER AT _____

.0	.10	.20	.30	.40	.50	.60	.70

ANGLE COEFFICIENT	DISTANCE FROM INITIAL POINT	WIDTH	DEPTH	OBSERVATION DEPTH	REVOLUTIONS	TIME IN SECONDS	VELOCITY		ADJUSTED FOR HORIZONTAL ANGLE OR -------	AREA	DISCHARGE	.75	REMARKS
							AT POINT	MEAN IN VERTICAL					
												.80	
												.85	
												.90	
												.92	
												.94	
												.96	
												.97	
												.98	
												.99	
⊙												1.00	
												.99	
												.98	
												.97	
												.96	
												.94	
												.92	
												.90	
												.85	
												.80	
												.75	

0	.10	.20	.30	.40	.50	.60	.70

Sheet No. _____ of _____ sheets

DISCHARGE MEASUREMENT SUMMARY SHEET

STATION NUMBER _____

DISCHARGE MEASUREMENTS OF _____ DURING THE YEAR ENDING SEPT. 30, 19__

NO.	DATE	MADE BY	WIDTH FEET	AREA SQ.FT.	MEAN VELOCITY FPS	GAGE HEIGHT FEET	DISCHARGE CFS	RATING		METHOD	NUMBER MEAS. SECTIONS	GAGE HEIGHT CHANGE FEET	TIME HOUR	MEAS. RATED	TEMP.		REMARKS
								SHIFT ADJ. FEET	PERCENT DIFF.						AIR	H_2O	

COPIED BY _____ COMPUTED BY _____ CHECKED BY _____

6.4 Data Analysis

Data analysis will answer the following questions:

1. Are there any differences between the baseline and development period in the physical and chemical parameters measured at each station?

2. Are any significant changes indicated in the relationships between control and treatment stations?

Appropriate tables and summaries of the data at each station will compare the current information with previously collected information. Maximum, minimum, and mean annual values will be listed for quick comparisons. Such comparisons will illustrate trends caused by natural variation and/or trends caused by project activities that may require further analysis and interpretation. Graphical and statistical (hypothesis) tests will then be employed.

6.4.1 Data Management

Water resources data collection and processing is supported by the WRSOC water resources computer programs which are compatible with the U.S. Geological Survey's data management system, WATSTORE. These data management procedures are needed for the quality assurance and quality control program discussed in Section 6.3. Data are processed according to the specific needs of each method. For example, stage, temperature, conductivity and water levels are recorded at 15-minute intervals on a digital paper tape by the field instruments. These tapes are collected monthly and translated by a special tape reader. A WRSOC computer program reduces the 96 daily values to a daily maximum, minimum, and mean. This program is like the one currently used by the U.S. Geological Survey. The program can apply shifts, time corrections, and rating tables to the raw values.

The daily values (discharge, Ec, and temperature) are reviewed manually for consistency, accuracy and completeness. The revised data are entered into WRSOC's computerized water resources daily values storage and retrieval system.

The water quality analyses performed by the USGS Central Laboratory in Denver, Colorado will provide automatic entry of water quality analyses into the water quality file of WATSTORE. This data can then be retrieved from storage and subsequently entered in WRSOC's system directly by magnetic tape.

Suspended sediment concentrations are determined at WRSOC laboratories. This and all other field-generated data, such as discharge measurements, and static water level measurements, are entered by means of a screen-formatted CRT terminal displaying a WRSOC update form. Data entry is verified by checking a printout of stored data against the field notes.

Significant figures for WRSOC water data is reported consistent with USGS WATSTORE standards. In addition, several computer programs are interactive with the WRSOC data base for statistical, graphical, and interpretive analyses on selectively retrieved data.

6.4.2 Graphical Interpretation and Analysis

Discharge and sediment rating curves will be used to determine daily streamflow quantity and suspended sediment discharge. Instantaneous flood peaks that might occur during operational monitoring can be estimated on site from high water marks and/or stage readings from the continuous recorder. Capacity rating curves developed for the water impoundments will determine the remaining storage capacity (freeboard) at critical times, ensuring a safe storage margin in the event of a 100-year storm. Table 6.4-1 summarizes the graphics and statistics used in the subdisciplines of surface water, ground water, and water quality.

Hydrographs of discharge, sediment discharge, ground water levels, temperature and conductivity are interpretive tools used in analyzing daily records. Comparisons of hydrographs illustrate the changes in these parameters seasonally or annually. Such hydrographs will be developed from data collected in the continuous monitoring program and from other available regional data.

Graphical relationships between selected water quality constituents will also be used. For instance, plotting conductivity versus discharge normally provide a well-defined relationship. Deviation from this correlation can be indicative of a chemical perturbation. Discharge will also be correlated with sediment concentration to monitor the changes occurring in sediment transport. Selected constituents will be correlated with total dissolved solids to detect changes in the relative contribution of these constituents to the total concentration.

Water quality constituents will be plotted on Trilinear diagrams and/or Stiff diagrams. Baseline data has identified specific water quality trends at each monitoring location. Hence, deviation from these trends can be indicative of a chemical perturbation.

6.4.3 Statistical Procedures

Selection of appropriate statistical analysis is important for proper interpretation of any data set. To determine if perturbations are occurring in hydrologic parameters, an adequate record of the baseline conditions must be available. Baseline monitoring of 1974-76 and interim monitoring of 1977-1981 resulted in a wide range of sample data from dry, wet and normal years. Thus, the data should approach a normal distribution.

TABLE 6.4-1

USE OF GRAPHS AND STATISTICAL ANALYSIS
IN WATER RESOURCES MONITORING

	Continuous Surface Water	Continuous Ground Water	Instantaneous Water Quality
Graphical Analysis			
Rating Curves	X		
Hydrographs	X	X	
X-Y Plots	X	X	X
Trilinear/Stiff Diagrams			X
Histograms			X
Statistical Analysis			
Chi square	X	X	X
t-test	X	X	
Z-standardization			X
ANOVA			X
Regression-correlation			X
Non-parametric tests(1)			X
Confidence limits	X	X	X
Cumulative density function	X	X	X

(1) To be conducted as needed.

Often raw data is not normally distributed, and data transformations can be performed to fit the data to a normal distribution. Log-transformation may provide a more normal distribution for water quality data. A sample size less than 30 observations will not often be normally distributed and in such cases non-parametric statistical tests are applied. Each parameter set will be tested by a Chi Square goodness of fit test to determine the distribution. If the data are not normally distributed, then non-parametric tests will be used. Normally distributed data will be analyzed by the t-test, the Z statistic, and analysis of variance. Relationships between parameters (ie., sediment to discharge) will be analyzed by correlation and regression analyses.

These statistical tests will indicate if significant changes have resulted from project-related perturbations. If significant perturbations at a station are detected, the control station will be similarly tested to determine whether the anomaly was project-related or merely a natural fluctuation. Some anomalies may occur, due to the relatively short record that has been obtained at the dry washes. For example, the runoff and water quality characteristics of Southam Canyon and Plant Site Wash are not yet been well-defined due to intermittent flow in these drainages. Continuation of monitoring at these stations during the pre-development phase will help to define natural variability at these sites.

A long-term objective of the water resources monitoring will be to test the null hypotheses:

H_0: There is no significant difference in the magnitude of the parameters being measured during baseline monitoring as compared to operational monitoring.

Continuous records of conductivity, and temperature from the White River stations will be analyzed using pairwise comparisons of current year to baseline mean values. First, the data will be log-transformed to approximate a normal distribution. Then, the geometric mean and geometric deviation will be computed for each parameter. These are analogous to the arithmetic mean and standard deviation of an untransformed distribution (Klusman, 1980). In a log-normal distribution, the geometric mean provides a more precise measure of the central tendency. The geometric mean of baseline data will be compared to the geometric mean during operations using a t-test. This test will indicate significant differences between the means. If no significant difference is found at the 1% level ($p = .01$), the null hypothesis is accepted. This test will detect short-term as well as long-term changes in the hydrologic environment at both control stations and at the treatment stations. This level was selected because of the large sample size (greater than 100) (Sokal and Rohlf 1969).

Comparison of means by a t-test will also be made for ground water levels at selected wells to detect significant decreases in water levels. If a significant difference in means is detected, the null hypothesis is rejected and additional tests are undertaken to determine the cause of the anomaly. For example, significant changes in the same parameter may be detected at both the control station and the treatment station. In such cases, the fluctuation may be evaluated as a natural environmental occurrence or a non-project related perturbation. It may not be due to project activities.

Due to a lack of continuous flow in Southam Canyon Wash and Plant Site Wash, the mean daily values of conductivity, sediment, or temperature may not be normally distributed. Therefore, a t-test cannot be applied to the data base. Non-parametric tests will be applied, as needed.

The null hypotheses will also be tested for instantaneous water quality sampling. Several constituents will be statistically analyzed and are designated as preliminary until the operational parameter list is finalized. Those parameters are shown in Table 6.4-2. These parameters have been identified (EPA 1980) as the primary chemical indicators of shale leachate or waste water effluents (see Table 6.1-1). Normally distributed data (log-transformed) collected during each year of operations will be analyzed by the Z statistic:

$$Z = \frac{x - \mu}{\sigma/n}$$

where x is the sample mean being tested, μ is the baseline mean, σ is the sample standard deviation and n is the sample size. The Z statistic is applied because it standardizes the normal distribution and can be used directly to test significance. For those stations with a limited baseline data (such as Southam Canyon and Plant Site Wash), a non-parametric test (i.e., Mann-Whitney U-test or ordered alternatives test) (Hollander and Wolfe 1973) will be used.

Ratios of selected water quality constituents to total dissolved solids will be monitored over the life of the project (as shown in Table 6.4-2). Significant differences in the ratios between baseline and operational data will be analyzed by the t-test.

Analysis of variance (ANOVA) will test the null hypothesis:

H_0: There is no significant difference in the parameters measured at control and treatment stations.

The ANOVA will be used to compare the variance between more than two sample means such as between stations or between years. For example, in Final Environmental Baseline Report (WRSP 1977) there was no significant difference in chemical constituents between White River stations.

TABLE 6.4-2

PRELIMINARY(1) WATER QUALITY CONSTITUENTS TO BE ANALYZED STATISTICALLY DURING PROJECT DEVELOPMENT

Constituent	Z Standardization /ANOVA	Discharge Regression	TDS Ratio
Sodium	SW/GW	SW	SW/GW
Sulfate	SW/GW	SW	SW/GW
Calcium	SW/GW	SW	SW/GW
Magnesium	SW/GW	SW	SW/GW
Bicarbonate	SW/GW	SW	SW/GW
Total Dissolved Solids	SW/GW	SW	
Chloride	SW/GW	SW	SW/GW
Fluoride	SW/GW	SW	SW/GW
Suspended sediment	SW/GW	SW	
Specific conductance	SW/GW	SW	SW/GW
Silica	SW/GW	SW	SW/GW
Oil and Grease	SW/GW	SW	
Ammonia Nitrogen	SW/GW	SW	
Organic Carbon	SW/GW	SW	
Total organic nitrogen	SW/GW	SW	
Phenols	SW/GW		
Sulfide	SW/GW		
Arsenic	SW/GW		
Boron	SW/GW		
Cadmium	SW/GW		
Mercury	SW/GW		
Molybdenum	SW/GW		
Nickel	SW/GW		
Selenium	SW/GW		
Zinc	SW/GW		

SW = to be tested for surface waters only.
SW/GW = to be tested for both surface and ground waters.

(1) Constituents may change depending upon the analysis of process waters.

Taking these results one step further, the determination of variation between stations over time can be tested. A nested ANOVA (Sokal and Rohlf 1969) will be used as shown in the example provided in Table 6.4-3. Because three of the original White River stations are discontinued (09306400, 09306500 and 09306600) and a new station was added during interim monitoring (09306395), only two stations 09306395 and 09306700, will be analyzed during development phases. The number of years tested will vary according to needs.

If the calculated F-statistic exceeds the critical F-value ($p = .05$), the null hypothesis is rejected. In such cases, the individual sample(s) causing the perturbation will be isolated by use of a hydrograph. Seasonal variation in chemical concentrations of the White River was established during baseline (WRSP 1977). Hydrographs will be analyzed visually to detect outliers from the normal seasonal trends. Detection of continued project-related perturbations would require initiation of operational changes. ANOVA testing will also determine if significant changes are occurring during each year of development at the stations on Evacuation Creek, Southam Canyon, and Plant Site Wash if data are adequate.

Water quality analyses from wells penetrating the Birds Nest Zone, the alluvial aquifers of Southam Canyon, Plant Site Wash, and the Upper Aquifer, will be grouped and tested individually using an ANOVA method (as found appropriate in the Final Environmental Baseline Report, WRSP 1977). The samples collected from the Birds Nest Zone during the baseline period indicated that there is a difference in chemical constituents along a diagonal line separating wells in the northeast from those in the southwest. Wells in this aquifer will be grouped according to this criterion for all statistical analyses.

The relationship of conductivity to discharge will be analyzed at each potentially impacted surface water station by correlation and regression analysis. Confidence limits will be determined and they

TABLE 6.4-3

ANALYSIS OF VARIANCE TO DETERMINE
DIFFERENCES IN CHEMICAL CONCENTRATIONS
AT TWO WHITE RIVER STATIONS OVER TIME

H_o: There is no significant change in the chemical concentrations at control and treatment stations over the first five years of monitoring.

Source of Variation	Degrees of Freedom	F-statistic
A. Among years A=5	A-1 = 4	A/B
B. Among locations B=2	A(B-1) = 5	B/C
C. Within samples (error) C=4	AB(C-1) = 30	
Total	ABC-1 = 39	

will be used to detect immediate as well as long-term changes from the baseline regression line. The results from instantaneous observations of conductivity and discharge will be plotted to see if the point falls within the 95% confidence limits. Also, the composited results from each year of operations are plotted and a comparison of the current regression line to the baseline regression line will be tested for parallelism (Hollander and Wolfe 1973). A change in slope in these regression lines may be indicative of a project-related perturbation. Several other surface water constituents will be analyzed by regression because of their dependency on discharge (see Table 6.4-2).

6.4.4 Computer Analysis/Simulations

WRSOC uses several application programs similar to those used by the U.S. Geological Survey in routine data analysis. Table 6.4-4 summarizes these computer applications for the water resources monitoring program. The WRSOC water resources data base is interfaced with these programs. Data from a particular station can be retrieved for any length of record and/or any specified number of parameters and be printed in a tabular format. Or the retrieved data can be applied directly to one of several statistical or graphical programs.

Water quality data will be analyzed by plotting Trilinear, Stiff and Ropes Diagrams on a line-printer. Baseline data will be compared to operational data using Trilinear diagrams. In addition, there are two programs for performing statistical tests of selected parameters. The program, ratio tables, will summarize selected data by maximum, minimum, mean and standard deviation. It will also compute ratios for selected variables and compute these same statistics for the ratios. The interactive statistical program (LISA) will test hypotheses using analysis of variance, regression, correlation, chi-square tests, frequency analysis, and log-transformations.

TABLE 6.4-4

WRSOC COMPUTER PROGRAM APPLICATIONS

Program Name	Monitoring Application
Water Quality Tables	Selective listing of water quality data in formatted tables.
Graph Plot (X,Y)	Plots any two parameters, computes correlation coefficient and regression equation
Trilinear Diagram	Plots several water quality analyses on one diagram
Stiff Diagram	Plots singular water quality analyses
Ropes Diagram	Plots frequency distribution of water quality constituents
Ratio Tables	Computes ratios between selected variables and summarizes maximum, minimum, mean, standard deviation, and sample size
Lafayette Interactive Statistical Analysis (LISA)	Statistical testing: analysis of variance, regression, correlation, Chi-square tests, frequency analysis, log-transformations

6.5 Trigger Values and Development of Contingency Plans

6.5.1 Trigger Values

"Trigger" values will be established as a means of detecting immediate environmental perturbations. In this manner, appropriate contingency measures can be implemented to prevent long-term degradation.

If the mean daily conductivity at the White River treatment station (09306700) exceeds the one percent frequency level (defined in baseline) for three consecutive days, duplicate water quality samples will be taken immediately and analyzed for parameters listed in Table 6.1-3.

The purpose of this replicate sampling is to determine a mean value for each constituent. Thus, instantaneous measurements can be statistically tested immediately after laboratory analysis. Each parameter will be tested using the Z-standardization at the 5% critical level. Rejection of the null hypothesis isolates those specific constituents causing the perturbation. Appropriate contingency measures are then implemented in consultation with the OSO and WRSOC.

A trigger value at the stations on Southam Canyon Wash and Plant Site Wash will be defined as any instantaneous field reading that plots above the upper confidence limit, established by a regression analysis of conductivity versus discharge, or sediment concentration versus discharge. Due to limited streamflow events at these sites, the 95% confidence limits are not well defined at this time. Therefore, the approximate confidence limits will be assumed to be of the same slope as the regression line and of a width defined by the highest and lowest outlier sampled to date. This method will be used until additional data are collected to more precisely define the confidence limits. Exceedence of this trigger value will prompt immediate replicate sampling.

Trigger values for grab samples from surface waters and ground waters during operations will be defined as any instantaneous water quality constituent that does not fall within 95% confidence limits of the baseline cummulative density function (frequency curve). Loftis and Ward (1981) have presented a method of analyzing for exceedences of a given water quality data base (i.e., baseline). Confidence limits will be determined for all water quality constituents listed in Table 6.4-2. Exceedances or violations would initiate immediate replicate sampling at the affected site. In addition to the above condition, any value exceeding the baseline maximum or whenever significant trends are detected, the value will be treated as a "trigger" value.

The WATSTORE computer system has established "threshold" values for flagging water quality constituents that are known to exceed biological tolerances set forth by EPA (1976). Because the WRSOC monitoring program uses the USGS Laboratory for water quality analysis, these values will be identified in samples taken for the monitoring program. Exceedence of these threshold values will trigger an investigation into the value. Several constituents may normally exceed these threshold values and documentation of these constituents will be made. However, if exceedences are detected for the first time at a station, this will trigger immediate action, and additional analysis to determine the cause of the anomaly.

6.5.2 Contingency Monitoring

Contingency monitoring will be implemented in response to several possible situations. These are outlined below:

In the event of an accidental spill or discharge: intensive water quality sampling for an expanded parameter list will be initiated immediately at several locations downstream of the source. The sampling will help determine the concentration and rate of movement of the contaminated water so that effective mitigation measures can be

employed. Repair of structural failures or seepage from retention dams will be made and appropriate remedial actions will be undertaken to clean up and eliminate water quality contamination.

In the event that a trigger value or a threshold value (from WATSTORE) is exceeded: suspect value(s) will be checked for human or instrument error. The next step will be to check the concurrent value(s) recorded at the control station or well. If the trigger value is only detected at the treatment site, a field reconnaissance of the area will be undertaken to inspect all retention basins and sediment basins for seeps, leaks, cracks, and remaining capacity (freeboard). Field measurements of conductivity, temperature, dissolved oxygen, and pH will be taken at the site.

If no sufficient explanation can be found for these suspect values during the field reconnaissance, then immediate contingency sampling would be implemented. This would require replicate sampling for the suspect constitutent at the site and at selected sites just upstream (upgradient) and downstream (downgradient) of the station (well). Sampling for an expanded parameter list may be required until the cause of the perturbation is determined.

In the event that ground water contingency monitoring is needed, additional alluvial and bedrock (see Evacuation Creek) aquifer wells will be sampled. Specifically, alluvial wells G-2A, G-4A and AG-7 will be sampled immediately and continue on a quarterly schedule. Bedrock aquifer wells G-15, G-21, P-2 lower and P-2 upper will be sampled immediately and continue on a semi-annual schedule. The proposed monitoring would continue until the source of the impact is located and mitigated.

In the event that a null hypothesis is rejected: trigger values have been established to provide an early warning system so that long-term environmental effects can be avoided. One possible cause for rejection

of a null hypothesis could be accidental or unknown spills or seeps that were later detected in water quality sampling or detected by continuous monitors. In either event, appropriate control measures would have been initiated at that time to clean up the contamination. Therefore, long-term degradation of water quality would not be likely.

Other possible causes for rejection of a null hypothesis are: 1) natural climatic and/or hydrologic extremes; 2) off-tract runoff events occurring between sampling stations; 3) variations in sampling time between treatment and control stations, and 4) effects of activities by other projects located upstream (upgradient) of WRSP. These possible causes will be evaluated in the event of rejection of a null hypothesis.

If, however, there continues to be significant changes in a specific parameter over several years (such as decreasing water levels in the Birds Nest Zone), then appropriate design changes in operational plans would be required, if this condition is identified as being project-related.

If no significant changes in the water quality or sediment characteristics of Evacuation Creek are detected during the first two years of operation, a reduced parameter list and/or a less frequent sampling schedule will be proposed for this drainage basin.

6.6 Precipitation and Evaporation Monitoring

6.6.1 Program Design and Rationale

The precipitation and evaporation programs have been designed to provide support data for the hydrologic, meteorologic, biologic and engineering tasks associated with the White River Shale Project.

The objective of the program is four-fold. First, in support of the hydrologic program, data will be used in flood frequency analysis. The

precipitation data will also be used to verify daily discharge calculations and water quality measurements. Second, the data will be used to determine the relationship between the project site and the regional precipitation and evaporation data. This relationship will then be used to verify the 100-year design storm and the analysis of other tract microclimate values. The third objective of the program is to assist in project design. The measurement of site-specific evaporation and the information generated by the first two objectives will provide data to assist in the design of holding ponds and processed shale disposal piles. Finally, the program will provide a data base that will support the aquatic, terrestrial biota, and revegetation studies being conducted on the tracts.

6.6.2 Parameters to be Studied

The parameters to be included in this monitoring program include precipitation, evaporation, temperature, relative humidity, and wind run. Precipitation (water equivalent) is monitored year round at the sites on or near the tracts. Evaporation is measured during the freeze-free period, usually May through September at two sites (Table 6.6-1). In addition, maximum and minimum air temperatures, relative humidity and wind run are being measured in Southam Canyon at one of the evaporation pans to assist in microclimate definition. The data collected here will provide information for necessary calculation of a climatic water balance (CWB) and supplement information needed for other biologic and vegetation programs. The CWB will be used to predict the expected water loss from on-site impoundments and assist in the design of revegetation programs.

6.6.3 Sampling Locations and Schedules

Precipitation

Precipitation will be monitored by either automatic recording or storage gauges at locations distributed throughout and near the tracts.

TABLE 6.6-1

PRECIPITATION AND EVAPORATION MONITORING
LOCATIONS AND SCHEDULING

Station Designation	Type of Gauge	Monitoring Period
Precipitation		
ARA-13	Recording	Year round
ARA-2	Recording	April through October
ARS-9	Recording	April through October
RA-4	Storage	Year round
RB-1	Storage	Year round
RS-10	Storage	Year round
RS-11	Storage	Year round
RS-13	Storage	Year round
RV-7	Storage	Year round
RV-8	Storage	Year round
Evaporation		
EVP-2	Pan(1)	April through October
EVP-13	Pan	April through October

(1) In addition to pan evaporation, wind run, maximum and minimum temperature, and relative humidity are monitored at this site.

The current location of the gauges are shown on Figure 6.6-1 (the specific gauge type used at each site is listed in Table 6.6-1). Station designations beginning with the letter "A" are automatic recording gauges. There are three such gauges on the tracts, of these one (ARA-13) is in operation year round and the other are operated during the storm season, April through October. Station designations beginning with the letter "R" are storage gauges. These gauges are to be operated year round.

The precipitation monitoring program has been designated to be flexible, when project needs dictate, gauges may be moved or added, to meet additonal monitoring needs.

Evaporation

The evaporation network will consist of two U.S. Bureau of Plant Industry Sunken Pans operated during the freeze-free period (usually May through October). The first pan is located on an exposed ridge in Southam Canyon and the second on a somewhat protected valley at the plant site. The need for multiple locations is a result of the effects of terrain and air flow on evaporation rates. The established network is expected to define characteristic terrain effects occurring on the tracts.

6.6.4 Methods

Recording precipitation gauges on the tracts are of the Fischer-Porter type which mechanically converts the depth of accumulated precipitation over a period of time to a code disk position. This code disk position is then recorded on a punched paper tape at selected intervals.

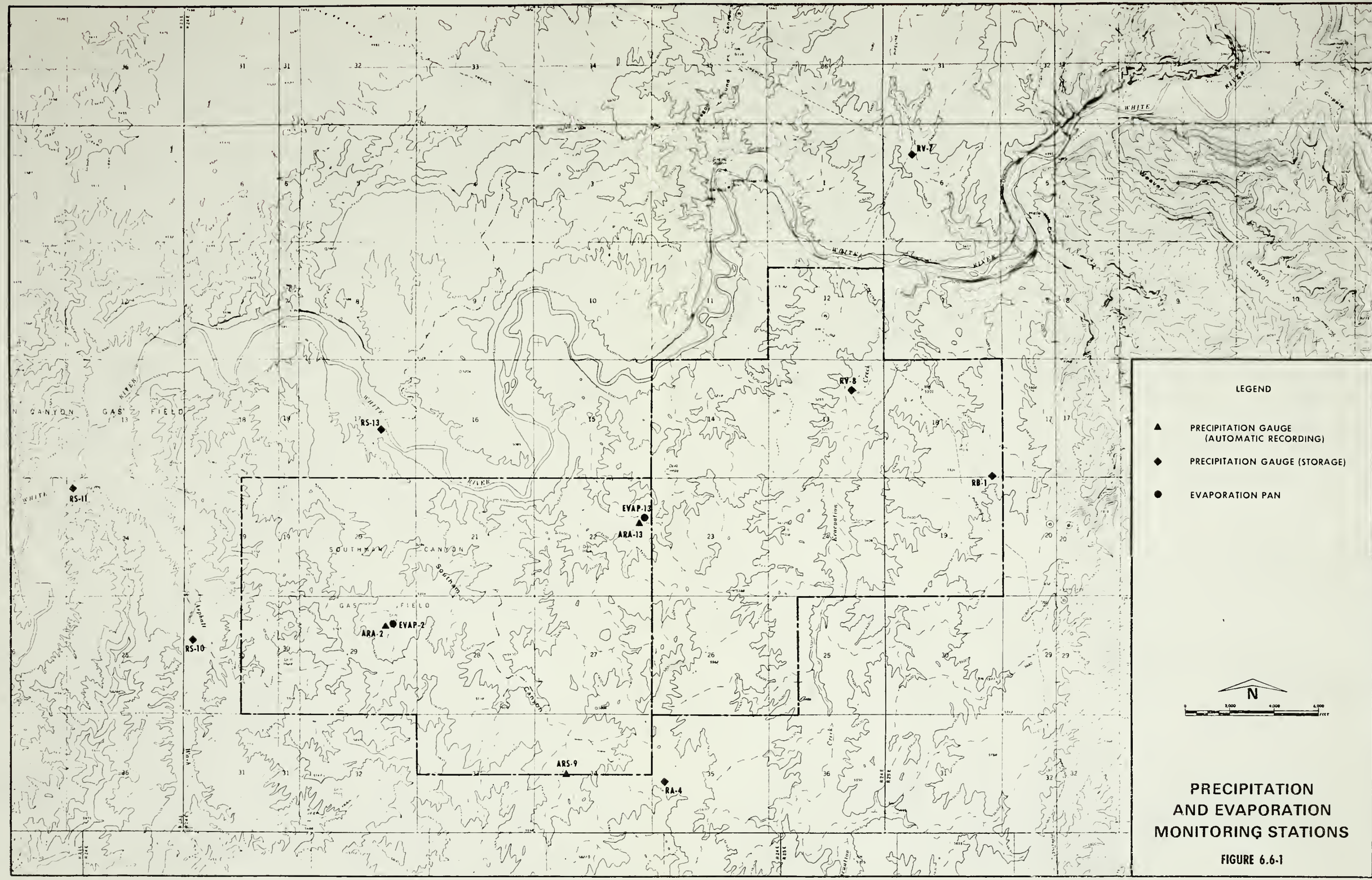
The measurement device consists of a collection bucket, a weighing device and an indicating dial to display accumulated precipitation. A recording mechanism operates with the measuring device to record, on

paper tape to the near 0.1 inch, the precipitation accumulated in a predetermined interval. The recording is in a standard binary-decimal code suitable for automatic machine processing. Visual readings can also be made as well.

Storage and precipitation gauge operations are comparatively simple. On a weekly or monthly schedule, depending on weather conditions, a field technician visits each storage gauge location. The gauges are composed of three basic components: a collection tube, a funnel and a storage chamber. During site visits the technician removes the collection tube and funnel from the storage container and carefully pours its contents into a graduated cylinder for direct reading of accumulated precipitation. To reduce the chance of evaporative loss from the gauges, a thin film of oil is placed in the storage container.

Evaporation measurements are made using a U.S. Bureau Plant Industry Sunken Evaporation Pan, still well and hook gauge. Evaporation readings are recorded on the pan during weekly visits. These readings are made by refilling the pan to the top of the hook gauge located inside the still well (this is a permanent reference level used for all visits). The measured volume of water required to refill the pan to this reference level is converted to inches of water lost from the pan since the last visit. The amount of precipitation since the last visit is added to this value, and the quantity is multiplied by the pan coefficient (0.95 for the pan type being used). The resulting calculated value is defined as total evaporation. Evaporation readings are recorded on the pans during monthly visits. Screens over the pans are used to keep wildlife from drinking the water.

Instrumentation and gauge locations have been summarized above in Table 6.6-1 and Figure 6.6.1 respectively.



PRECIPITATION AND EVAPORATION MONITORING STATIONS

FIGURE 6.6-1

Data Management

Precipitation

Precipitation data will enter the water resouces data management system in two forms. Data collected by the automatic gauges are in-put as daily totals. Data from storage gauges, since not monitored daily will be entered as a cumulative value, generally as the monthly total.

Evaporation

All data will be entered as a cumulative value, generally as a monthly total.

6.6.5 Data Analysis

Data will be analyzed both graphically and statistically to determine:

1. Seasonal and annual precipitation and evaporation patterns on the tracts.
2. Mean and extreme precipitation events.

As the precipitation data base is expanded, a site-specific analysis of precipitation frequency will be conducted. This analysis will compare data collected on-site to those published in the National Weather Bureau's Technical Paper No. 40. The data will help determine the 100-year return interval, 24-hour storm event for the tracts.

This analysis will be performed using additional data collected in the air monitoring program on major summer thunderstorm events to identify their storm track across the tracts. The evaporation data will be analyzed through the use of the "Watbug" climatic water budget computer model to determine probable water loss from on-tract sites.

The results of the precipitation and evaporation data will be reported as special studies and summarized in the annual water resources data reports.

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7.0 SPECIAL STUDIES

The WRSOC has identified several areas of study important to our evaluation of the environmental effect of Tract Ua and Ub development which do not fit well under any specific discipline. This chapter describes what is planned for each of these special studies.

The topics addressed in the following sections include:

- Demonstration of Monitoring Program Elements
- Revegetation/Reclamation Research
- Phase I Processed Shale Research Plot
- Subsidence Monitoring
- Hazardous Waste Monitoring
- Sediment Characterization Study

7.1 Demonstration of Monitoring Program Elements

A primary goal of the field environmental monitoring program described in this manual is the identification and assessment of environmental change (particularly as it may affect the biological community) due to development of the oil shale resource on Tracts Ua and Ub. Our approach to monitoring utilizes the scientific method to design field studies which will document actual environmental effects of oil shale processing ecosystems.

Laboratory bioassays have been important in providing "indications" of the effects of oil shale by-products on the environment. However, they cannot provide the complete answers due to their necessary emphasis upon single species under controlled growth conditions. These conditions do not expose the organisms to the expected level of contamination under natural stress situations which are due to variation of the physical and biological environment. Thus, there is a need to conduct studies in the field under natural conditions to verify that elements within the monitoring program will be sensitive to the changes which can be expected to occur from the WRSP. This section describes our plans to conduct such a study.

7.1.1 Objectives

The demonstration of elements within our field environmental monitoring program involves a four-year phased study which is designed to provide the following:

- Identify which process-related compounds in the air or water environments acting alone or synergistically can cause change in the plant and animal communities, both terrestrial and aquatic; particularly, those which are damaging to individuals or to ecosystem productivity and diversity.

- The level (threshold) of those compounds causing damage will be quantified.

- The ability of the ecosystem to recover from the introduction of those compounds will be investigated so that management alternatives of action/no action may be justified and action alternatives developed.

- For compounds which may cause an adverse and irreversible change, mitigation measures will be determined. This can involve process design revisions to reduce the strength of the point source and/or in situ modifications to accelerate ecosystem recovery.

- The development of effective monitoring tools to allow quantification of impact.

7.1.2 Aquatic Study Design

Rationale

Sources of potential pollutants into the aquatic system include: 1) airborne processed shale dust and other particulates; 2) overland flow of particles and leachates from raw and processed shale; 3) ground water infiltration of these products, and 4) accidental discharges. These introductions may involve both short- and long-term doses at concentrations of pollutants which can range from near zero to above permissible thresholds.

Conventional bioassay studies have shown that processed shale leachates have stimulatory effects at very low concentrations and depressing effects at higher concentrations. In-situ experiments by WRSOC consultants have demonstrated effects that are both stimulatory and depressing. These compounds occurred less in concentrations of less

than 10% of that which demonstrated no effect in the laboratory and were shown to vary on a seasonal basis. Further, our work in the White River has documented that the dynamic nature of the river is regulated by individual stream events.

Based upon these data, this study will be designed to address the following influencing factors:

- The manner by which leachate and/or particulate matter can be introduced into the aquatic system (i.e., through short-term overland flow during storm events, via long-term ground water infiltration, or direct accidential discharge).

- The seasonal susceptibility of organisms present in the aquatic system.

- In situ experiments designed to eliminate the need for extrapolation of information from laboratory bioassays and to generate information on the natural system as it is affected by environmental conditions.

Parameters

The experimental design of this project will involve approximately bi-monthly sampling. Production/respiration (P/R) chambers will be placed in the stream using natural substrate. The chambers will be in sufficient replicates to contain the following treatments: 1) controls; 2) simulated surface discharges (one day to one week long; high and intermediate level leachate addition); 3) simulated ground water flow (continuous low level leachate addition), and 4) the ambient river environment.

The advantages of using this approach are: 1) convenience of using only a selected portion of the ecosystem; 2) obtaining replication while

using the natural environment; 3) minimum amount of leachate needed for experimental design; 4) the high sensitivity of the P/R chambers for measuring ecosystem parameters, and 5) the proven use of these P/R chambers with continuous monitoring.

Field monitoring for this program will be coordinated with the on-going aquatic biology monitoring program described in Chapter 4.0. Monitoring parameters will be selected to provide information on various influencing factors including physical factors (such as vertical illumination through the water column and temperature), abiotic factors (such as channel geomorphology and fluvitile characteristics), and biotic factors. The biotic component will be separated into three major trophic structures; primary producers, secondary-tertiary producers (consumers) and decomposers. Both structural and functional parameters will be measured.

7.1.3 Terrestrial Study Design

Rationale

Sources of potential pollutants into the terrestrial ecosystem include: 1) airborne raw and processed shale dust and other particulates; 2) climatic erosion of particles, overland flow, and deposition of leachates from raw and processed shale piles, and 3) airborne emissions from the retorting processes.

The approach taken in this study will be to evaluate subcomponents of the terrestrial ecosystem. These *in situ* sites will be representative of and include the major structural and functional features of the larger ecosystem.

The study will be designed to address the following influencing factors:

- Studies will be conducted on a small scale to allow quantification of plant-soil system relationships.

- Studies will be conducted in situ because of plant and soil susceptibility to environmental variation.

- Studies will address the individual and synergistic effects of gaseous pollutants and particulate matter on the terrestrial system.

- Studies will address short-term and long-term doses at varying levels to evaluate threshold values.

- Seasonal variability will also be evaluated in identifying probable response.

Parameters

The experimental design of this project will involve a sampling schedule keyed to the important physiological functions of the system under study. It will also be coordinated with our on-going terrestrial flora and fauna studies. Information on weather conditions will be input to the program from our on-going air and water resource monitoring programs. The following study areas will be evaluated.

- Selection of Control/Treatment Sites - Study sites will be selected by cluster analysis using the most similar paired plots for control/treatment comparisons. Input to the analyses will be soil type, aspect, slope, shrub volume, and plant species, composition, and density. The Southam Canyon area will be used for these studies.

- Soils Response to Project Discharges - Studies will be conducted to evaluate the effects of project discharges on the

soil (i.e. texture, color, composition), chemical (i.e. pH, electrical conductivity, elemental), and biological (i.e. respiration rates, soil invertebrate and soil mycorrhizal associations, abundance, and activity) parameters will be evaluated. Terrestrial invertebrate relationships will also be investigated. A pair of sites will be used to determine the effects of precipitation on soil respiration and heavy metal leachate from processed shale dust.

- Plant Response to Project Discharges - Studies will be conducted to evaluate the effects of process discharges, particularly processed shale dust, on area vegetation. Community-level physical (i.e. cover, density, seed production, annual plant biomass), species-level physical (i.e. plant volume, leaf temperature, root growth, plant phenology and vigor), chemical (i.e. elemental levels), and biological (i.e. net CO_2 exchange, photosynthesis, respiration, transpiration) parameters will be evaluated. Plant respiration response to processed shale dust and gaseous pollutants (SO_2, NO_x, and ozone) will also be studied. Gas-exchange chambers will be used *in situ* for this portion of the study.

7.1.4 Results

This program will analyze the persistence, fate, and bioaccumulation of pollutants in the aquatic and terrestrial systems. By following the seasonal patterns of the structural and functional parameters and comparing treatment and control stations during and after dosing, the resiliency of the systems can be determined. Thus, the program will document the levels at which environmental damage will begin and provide evidence of our monitoring program's ability to detect such levels.

7.2 Revegetation/Reclamation Studies

7.2.1 Introduction

Since 1975, studies have been carried out for the WRSP concerning the revegetation of disturbed sites and reclamation of processed shale disposal areas. The research program was developed around a philosophy to utilize natural processes and materials and to minimize the requirements for scarce resources such as water and topsoil. These studies have addressed several objectives: 1) to provide data on processed shale characteristics relevant to reclamation; 2) to describe the physical and chemical decomposition of processed shale; 3) to determine plant tolerances to processed shale characteristics; 4) to assess the suitability of various plant materials for reclamation; 5) to develop plant establishment methods, and 6) to measure topsoil response to long-term storage. A list of publications resulting from the research program is given in Section 7.2.4 (Appendix).

This section describes completed, on-going, and planned studies within the framework of a comprehensive revegetation/reclamation study program. Some of the studies have been completed while others are still in progress or are in the planning stage (site selection) such as the Phase I processed shale test area. Several completed studies are being monitored for long-term effects. A summary of the reclamation research from November 1974 to December 31, 1978, was published in June 1979. The results of the on-going research program have also been published in the annual environmental progress reports for WRSP.

7.2.2 Location of Studies

The principal research site is in Section 6 (R24E, T10S), north of the White River on privately-owned land. Numerous small sites on Tracts Ua and Ub, which were disturbed by the geological resources drilling program during the Baseline Study have been used for plant establishment

studies. Plant establishment techniques are being studied on a site at Anvil Points, Colorado, previously used for processed shale compaction studies.

Table 7.2-1 lists the study sites and types of studies conducted for WRSP. Figure 7.2-1 shows the locations of the study areas on Ua/Ub and nearby.

7.2.3 Types of Reclamation Studies

Over 50 studies have been conducted to date in the WRSP reclamation research program. The results of these studies have received wide distribution and have been subject to significant "peer" review. Following is a summary of the various reclamation studies:

Processed Shale Characteristics Related to Revegetation

Rationale. Selection of species to revegetate processed shale depends on the chemical and physical nature of the processed shale, especially the concentration of elements and their leachability. Data on the rate of physical and cemical decomposition of processed shale will guide timing of reclamation activities.

Questions to be Answered.

1. Are chemical and physical characteristics of processed shale suitable for the growth of certain native plant species adapted to stress conditions?

2. Can undesirable physical and chemical characteristics of processed oil shale be modified or avoided by methods of land and plant manipulation?

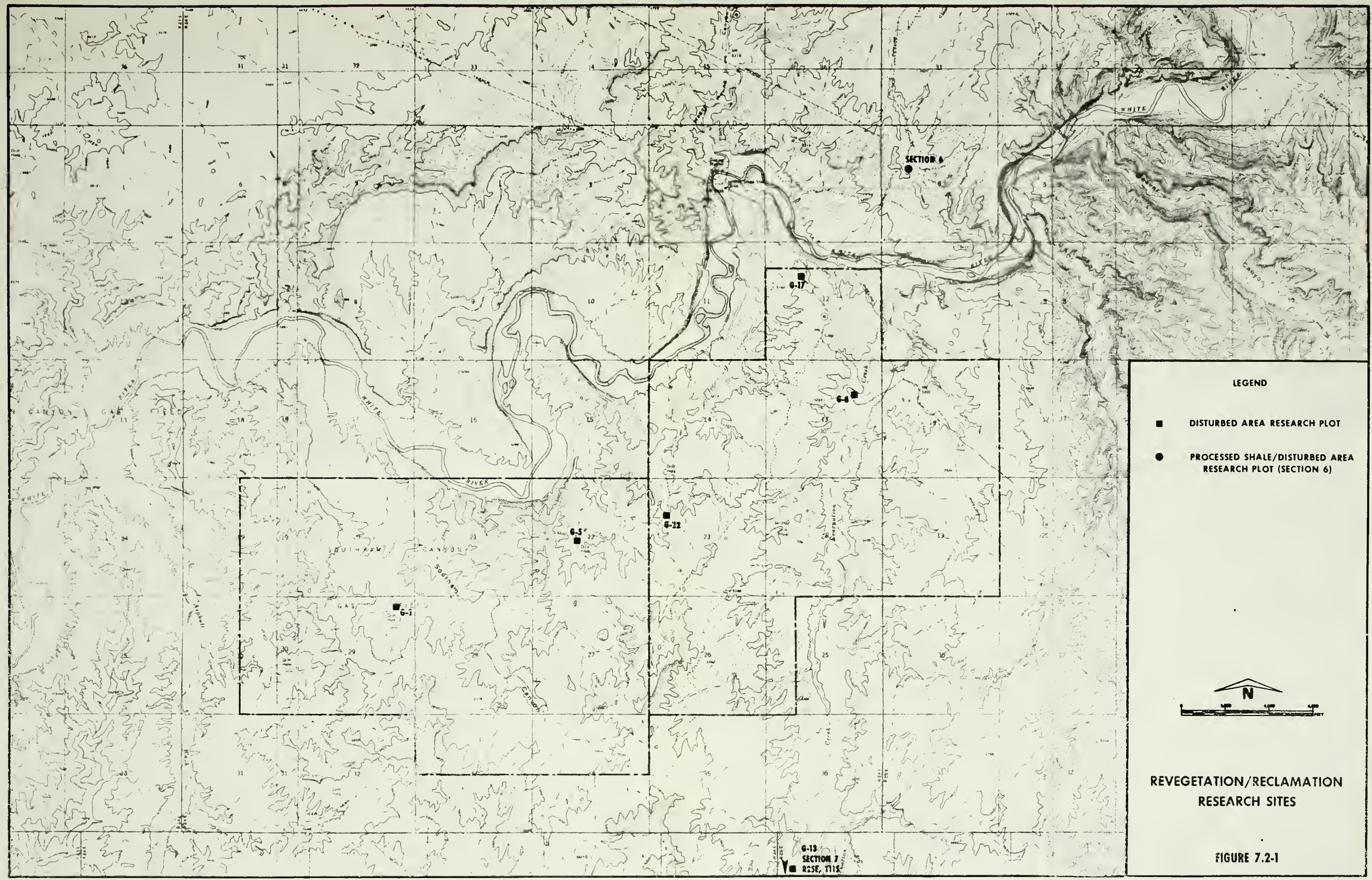
TABLE 7.2-1

STUDY SITES FOR WRSP REVEGETATION/
RECLAMATION STUDIES

Name of Study Site	Location	Years of Study	Types of Studies Conducted
Section 6	North of White River	1976-80	Plant establishment
		1975-79	Plant growth on shale
		1976-79	Water harvesting
		1976-77	Surface stabilization
		1977-	Pilot model, disposal pile
		1977-80	Competition management
		1981-	Topsoil management
		1981-	Habitat improvement
G-5/G-22	Tract Ua	1975-78	Plant establishment and species suitability
G-13	South of Tracts Watson Area	1975-78	Plant establishment and species suitability
G-3	Tract Ua	1975-78	Plant establishment and species suitability
G-8	Tract Ub	1975-78	Plant establishment, species suitability and
		1977-80	competition management
G-17	Tract Ub	1975-79	Plant establishment methods, species suitability
Processed Shale Compaction Site	Anvil Points, Colorado	1978-79	Water harvesting
		1979-	Topsoil use in shale trenches
		1979-	Plant species establishment in topsoil trench
		1979-	Plant species establishment in shale
		1979-	Mycorrhizae in processed shale
USU Laboratories and greenhouse	Logan, Utah	1975-79	Processed shale characteristics
		1976-79	Physiological responses to shale

TABLE 7.2-1 (cont.)

Name of Study Site	Location	Years of Study	Types of Studies Conducted
		1978-79	Water harvesting
		1978-80	Leaching studies
		1975-81	Plant materials suitability
		1975-79	Seed biology and seedling growth
		1978-80	Mycorrhizae studies
Native Plants	Salt Lake City	1981-	Processed shale characteristics, leaching, and physiological response to shale



REVEGETATION/RECLAMATION RESEARCH SITES

FIGURE 7.2-1

Information Requirements. Some of the basic information needed are standard chemical contents relevant to plant growth, chemical and physical decomposition (weathering) rates, and leaching loss rates of salts in the processed shale.

Studies Conducted or Planned.

1. Laboratory analysis of processed shale for plant-related parameters and soil compaction (one study completed on Union and Paraho processed shale and one planned for circular-grate processed shale). The chemical analysis of circular grate processed shale will be performed including the following parameters: pH, EC, N (total and nitrate), P, K, Ca, Na, Mg, B, Mo, As, Mg, Cd, Fe, Se, F and SO_4.

2. Leachability of salts from columns of shale under various environmental conditions and water amounts (two studies completed and one planned for circular-grate processed shale).

3. Accumulation of salts at various depths under limited leaching conditions (two studies completed).

4. Tracking nutrient cycling in a processed oil shale disposal site (one study in progress and one planned).

Plant Tolerance to the Extreme Characteristics of Processed Shale

Rationale. The success of establishing native plant species on processed shale depends on the plant's ability to tolerate stresses such as salinity, pH, and moisture regimes associated with processed shale. Plant tolerance studies in the greenhouse, laboratory, and field can provide data from which to predict plant performance.

Questions to be Answered. Are upper limits of plant tolerance to stress (pH, salinity, drought, temperature) within the range of values associated with processed oil shale?

Information Requirements. Information is needed on the upper tolerance limits of plant species for total salts measured as electrical conductivity (EC), the range of tolerance to individual salts, plant growth response over a range of pH values, and plant growth and/or mortality over a range of moisture stress conditions.

Studies Conducted or Planned.

1. Tolerance of Atriplex species to various salinity levels (completed).

2. Plant response to pH of processed shale (completed).

3. Growth of cuneate saltbush in highly alkaline processed shale and raw soil (four studies completed).

4. Fertility responses of native species grown in leached processed shale (four studies completed).

5. Root growth into processed shale (four studies completed).

6. Growth of Atriplex gardneri on circular-grate processed shale (two studies planned).

Native Plant Materials for Vegetating Disturbed Sites and Processed Shale

Rationale. To utilize native species for large rehabilitation projects in cold-desert areas, new information must be generated concerning seed

production, germination requirements, propagation methods and ways to provide plant materials in a suitable form.

Questions to be Answered. Do native species have characteristics in seed preparation, germination, vegetative propagation and plant materials processing as cultivated or introduced species that are suitable for use in revegetating disturbed areas and processed shale?

Information Requirements. A wide range of information is needed concerning the morphological and physiological characteristics of the various native species found on Tracts Ua and Ub. This information must be sufficient to guide plant materials acquisition and preparation for use in reclamation. In many cases the biological characteristics of native plants are slightly different from other species and must be treated individually.

Studies Conducted or Planned.

1. Plant propagation, seedling growth and seed biology of native species (six studies completed).

2. Seed maturity, harvesting and cleaning of various native species (four studies completed).

3. Container size as a factor in vegetative propagation of native shrub species for reclamation uses (three studies completed).

Establishment of Plants on Disturbed Sites

Rationale. Many sites are denuded or reduced in vegetative cover in the process of land exploration and development. They require special reclamation measures in semi-arid regions. Such measures must be specific for site conditions and may go beyond usual seeding technique.

Questions to be Answered. Will there be optimum species, times, and planting methods for plant establishment under stress conditions?

Information Requirement. Information is needed to develop methods to: improve site conditions; determine the most favorable season for planting; assess suitability of plant materials, and evaluate means for controlling plant competition.

Studies Conducted or Planned.

1. Species suitability for various disturbed sites (two studies completed).

2. Season, planting methods, and types of native planting materials (two studies completed).

3. Optimum age of transplants and methods for increasing transplant success (three studies completed).

4. Control of competition to increase transplant survival (two studies completed).

Establishment of Plants to Stabilize Processed Shale

Rationale. Observation of processed shale characteristics and the range of native plant tolerances to stress indicate the probability that rehabilitation of processed shale will be successful. What is needed are reclamation programs which understand and utilize the tolerances of native plants while at the same time optimize use of limited soil and water resources. WRSP's general strategy is to place soil in V-shaped trenches created on the surface of a processed shale disposal pile. Transplants are then planted into the soil to begin the process of stabilization and plant succession. Small slopes adjacent to the soil trenches harvest precipitation to augment soil moisture.

Questions to be Answered. Is plant establishment and growth on a processed shale disposal pile possible within physiological limits of native plants and shale modification strategies?

Information Requirements. Information needs concern strategies useful to modify processed shale characteristics such as migration of salts to the shale surface, root growth in soil and shale, salt movement from shale to soil, amount of water harvested, plant update of salts and trace elements, and plant survival.

Studies Conducted or Planned.

1. Pilot model of a shale disposal pile (one study continuing).

2. A field study of plant growth in a soil filled trench in a processed oil shale disposal site (two studies continuing).

3. Salt migration in soil and processed shale under field conditions (two studies continuing).

4. Water harvesting from a processed shale disposal pile (three studies completed).

5. Plant uptake of salts and heavy metals from processed oil shale (one study continuing).

Leachability of Salts from Processed Shale

Rationale. Reduction of salts in processed shale disposal areas may be an important factor for the establishment and long-term survival of plants. The leachability of salts under natural conditions or imposed management will be important to determine the best reclamation methods.

Questions to be Answered. Are salts contained in processed shale readily leached with sufficient water?

Information Requirements. Information is needed on the amount of water necessary to leach salts from shale to an EC less than 3 mmhos/cm^2, specific ion leachability, the influence of partial leaching on salt

migration distance, and the effect of environmental factors, such as surface heat, on upward salt migration.

Studies Conducted or Planned.

1. Amount of water required to leach processed shale (one study completed and one planned).

2. Factors affecting leachability of various salts in processed shale (one study completed).

3. Depth of salt migration as influenced by various amounts of applied water (one study completed).

Storage Effects on Topsoil

Rationale. To meet requirements for topsoil in plant establishment on a processed shale site, topsoil will have to be removed prior to shale disposal. Topsoil storage prior to reapplication is expected to alter its biological and chemical characteristics.

Questions to be Answered. Does storage of topsoil alter its biological or chemical properties?

Information Requirements. Various biological characteristics of soils are being studied routinely in the environmental monitoring program. Data on the effects of storage time and depth in the topsoil storage pile are needed to determine if storage causes a significant loss in soil favorability. Further, there is a need to determine the effects of soil storage on mycorrhizae as well as the amount of mycorrhizae necessary for successful plant establishment.

Studies Conducted or Planned.

1. Beneficial mycorrhizae influences on plant establishment in soil and processed shale (three studies completed).

2. Influence of time and depth of topsoil storage on biological activity (three studies in progress).

3. Soil chemical changes caused by topsoil storage time and depth (two studies planned).

4. Development of methods for innoculating container-grown plants with local mycorrhizae strains (monitoring on-going study by outside investigator).

Interplanting of Transplants to Enhance Wildlife Habitat

Rationale. As part of the wildlife management plan, areas adjacent to the plant site and the processed shale disposal area will be planted or seeded to increase the density and cover of plants desirable for wildlife habitat. Previous studies on plant establishment have been carried out on cleared areas, thus there is a need to study plant establishment in an existing stand of vegetation.

Questions to be Answered. Is greater success in plant establishment possible by transplanting container-grown plants into an existing plant community than by broadcast seeding?

Information Requirements. Information is needed to determine the most effective method of plant establishment and the kinds of species to be used in interplanting/interseeding operations.

Studies Conducted or Planned. Planting and seeding into an existing shrub community to enhance wildlife habitat (one study in progress).

Colonization of Plant Species on Processed Shale

Rationale. Observations indicate that several annual plant species have been able to germinate and grow directly on processed shale at

Anvil Points, Colorado. Monitoring the growth and other aspects of these species can provide useful information on the contribution of these species to surface stability and microsite conditions.

Questions to be Answered. Can natural colonization by plants favorably modify surface conditions of a processed shale disposal area?

Information Requirements. Information is needed on the kinds of colonization species involved, the amount of cover developed, the amount of litter deposited, and the influence of litter on surface chemical conditions and particle stability.

Studies Conducted or Planned. An examination of colonizer (weed) species and their influence on surface conditions of a processed shale disposal pile (one study in progress).

Reducing Wildlife Impacts to Plant Species on Revegetated Sites

Rationale. Small mammals can create a serious threat to establishment of plant species in a reclamation program. Environmentally sensitive means to reduce animal impacts are needed to assure revegetation success.

Questions to be Answered. Can small mammals and other wildlife species be acceptably deterred from grazing or consuming plants established for reclamation purposes?

Information Requirements. Information is needed on the effectiveness of fences, repellents, or other biological agents to restrict use of newly revegetated areas by various wildlife species.

Studies Conducted or Planned. A comparison of various methods for protecting revegetated areas from excessive use by wildlife species (three studies planned).

7.2.4 Appendix

The following articles/reports have been published on the WRSP revegetation/reclamation research program:

Alvarez-Cordero, Eduardo and C.M. McKell. 1979. Vegetative propagation of big sagebrush (Artemisia tridentata) J. Range Manage. 32.

Barker, J.R. and C.M. McKell. 1979. Growth of seedlings and stem cuttings of two salt-desert shrubs in containers prior to field planting. Reclamation Review, Vol. 2, pp. 85-91.

Crofts, K.A. and C.M. McKell. 1977. A bibliography of perennial Atriplex Species of the Western United States. Utah Agriculture Experiment Station Land Rehabilitation Series No. 3. 22 pp.

_____. 1977. Sources of seeds and planting materials in the Western States for land rehabilitation projects. Utah Agricultural Experiment Station Land Rehabilitation. Series No. 4. 19 pp.

Harthill, M. and C.M. McKell. 1979. Ecological stability--is this a realistic goal for arid land rehabilitation? p. 557-567. In Wali, M.K. (ed.) Ecology and Coal Resource Development. June 1978. U. of N. Pergamon Press, N.Y.

Institute for Land Rehabilitation. 1978. Rehabilitation of western wildlife habitat: A review. U.S. Fish and Wildlife Service. FWS/OBS 78/86.

_____. 1979. Rehabilitation of disturbed sites and oil shale disposal sites. Final Report to White River Shale Project. Utah State University.

_____. 1979. Selection, propagation and field establishment of native plant species on disturbed arid lands. Utah Agric. Expt. Stn. Bulletin 500. 49 pp.

McKell, C.M. 1978. Establishment of native plants for the rehabilitation of Paraho processed oil shale in an arid environment, p. 13-32. In R.A. Wright (ed.). The Reclamation of Disturbed Arid Lands, Univ. New Mexico Press.

McKell, C.M., G.A. Van Epps and S.G. Richardson. 1979. Plant establishment research on disturbed arid lands in the West. Surface Coal Mining and Reclamation Symposium, Proc. Coal Conference and Expo V. Louisville, Ky.

Richardson, S.G. and C.M. McKell. 1979. Response of Atriplex canescens to potassium fertilization, soil moisture and salinity of processed oil shale. Proc. Soc. for Range Management Meeting, Casper, Wyo., Feb. 1979.

_____. 1980. Salt tolerance of two saltbush species grown in processed oil shale. J. Range Manage. 33:460-462.

_____. 1980. Water relations of Atriplex canescens as affected by the salinity and moisture percentage of processed oil shale. Agron. J. 72:946-950.

Van Epps, G. and C.M. McKell. 1976. Plant rehabilitation studies on disturbed soils of the oil shale region of Utah. Proc. Soc. Range Manage. meetings, Omaha, Nebraska, February.

_____. 1979. Major criteria and procedures for selecting and establishing range shrubs as rehabilitation of disturbed lands. Proc. of First International Rangeland Congress p. 352-354.

_____. 1980. Revegetation of disturbed sites in the salt desert range of the Intermountain West. Utah Agric. Expt. Stn. Land Rehabilitation Series No. 5. 22 pp.

Wagenet, R.J., D.F. Fransway and C.M. McKell. 1980. Oil shale potential resource and possible environment problem. Utah Science 41(2):44-48.

7.3 Phase I Processed Shale Research Plot

As discussed in Section 7.2, WRSOC has since 1975 conducted applied research applicable to the reclamation of processed shale. Several significant studies have been conducted in Colorado to evaluate the environmental consequences of processed shale disposal using various methods and the probability of success for vegetating the area. However, due to insufficient volumes of processed shale, large-scale studies have not been conducted using Utah oil shale.

The study outlined in this section describes WRSOC's plans to collect additional information from a large-scale research plot of processed shale produced shorter after the start-up of the Phase I processing facilities. This program will be further defined, in consultation with the Oil Shale Office, as our operation date approaches and as further information becomes available from WRSOC's revegetation/reclamation research program and from similar research efforts conducted by other oil shale developers.

7.3.1 Purpose

The purpose of the Phase I processed shale research plot is to provide a site for both engineering and reclamation studies. Each of the studies will be interactive. The plot is needed in Phase I in order to extend small-scale plot, laboratory, and greenhouse studies into near commercial scale. Results will be used to validate WRSOC's reclamation plan for the WRSP as required by terms of the lease.

7.3.2 Location

The Phase I processed shale disposal piles will be constructed in a side canyon to Southam Canyon south of the mine shaft area (Section 27). The processed shale research plot will be established in this area but will be separated from the main Phase I pile to allow for

long-term, uninterrupted research efforts. The experimental plot will have a surface area of approximately 25 acres and a depth sufficient to allow realistic compaction and hydrological studies and testing of our reclamation plans. A dam and reservoir will be constructed down-gradient of the pile to collect any surface runoff or leachate from the pile.

7.3.3 Development

Topsoil will be salvaged and stockpiled from the area of the test pile. Processed shale will be deposited by bottom dump trucks and distributed by scrapers such that the pile is brought up in uniform lifts. The depths of lifts and compaction loading will be varied throughout the test pile depending upon the physical properties of the processed shale. Compaction tests will be conducted routinely to evaluate different methods of compaction. The pile will be evaluated to determine its geological stability, permeability, and its potential to erode (and methods to control erosion).

7.3.4 Monitoring Studies

Air Resources

Ambient total suspended particulate measurements will be taken around the processed shale research plot as it is deposited and following compaction to determine an appropriate emission factor for such operations and evaluate the effectiveness of our dust suppression practices. The sampling will be by hi-vol collectors and through visual observations.

Water Resources

A lysimeter will be constructed in the test pile in order to study its hydrological properties. Water samples taken from the lysimeter will

be subjected to quantitative analyses to characterize the leachate. Additionally, provisions will be made to obtain moisture and water quality characteristics at various locations and depths throughout the experimental pile. Examples of instrumentation which may be used are tensiometers, salinity sensors, neutron probes (access tubes) and vacuum lysimeters. A principal goal of this part of the monitoring program is the calculation (estimation) of a water balance around the pile.

Terrestrial Flora

A major part of the field test area will be devoted to revegetation and related studies such as surface stabilization, chemical-physical weathering of processed shale, nutrient cycling, water harvesting, and wildlife impacts on vegetation establishment. The research on revegetation will include such studies as plant mineral uptake, plant performance both top growth and root growth, plant longevity, soil microbiology, and minimal fertilizer and water requirements for establishment and growth. Also important are estimations of plant cover, species density, and biomass production. Our studies will also assess succession of transplanted species and volunteer plant establishment. This data will allow us to judge the success of our program in creating suitable wildlife habitat for forage and cover for concealment.

Terrestrial Fauna

When the processed shale pile is formed and vegetated, two studies on animals will occur. The first concerns the magnitude, composition and rate that invertebrates and vertebrates invade the pile and the second concerns controlling damage to newly planted or seeded grasses and shrubs on the pile.

The first study will begin as the pile is formed and vegetation is initiated. Invertebrates and vertebrates will be captured in a

manner which will allow documentation of the frequency of use and population size. It may be that some invading species will be detrimental and others beneficial to initial vegetation. If this is the case, select animals can be controlled prior to and during the early stages of reclamation.

The second study will measure invertebrate and vertebrate damage to selected floral species and the control of this damage through physical barriers, repellents and, if necessary, the short-term use of pesticides. The objective will be to give the vegetation a grazing-free period in order to increase their vigor and be able to withstand grazing pressures.

A series of test plots, sampling regimes, and repellent or pesticide concentrations will be used on the test pile to determine the most efficient and effective methodology to be used on the main processed shale pile.

7.4 Subsidence Monitoring

7.4.1 Program Design and Rationale

The objective of this monitoring program will be to measure surface subsidence on the tracts that could occur as a result of underground mining activities. Results of this program will be used to design and implement contingency measures that may be necessary. Such measures would essentially involve questions of stability in surface structures and drainage or seepage controls. This surface subsidence study will be coordinated with studies of mine stability performed by the mine engineering staff.

7.4.2 Parameters to be Studied

Several parameters will be used to assess potential and actual subsidence. Surface measurements will involve the precise determination of both horizontal and vertical components of above-ground movement occurring in areas overlying and adjacent to the mine zone. Additional data which could indicate potential subsidence problems will be available from the mine stability monitoring program. These data are expected to include seismic or acoustic monitoring, and underground surveys to determine relative vertical movement between the floor and back of the mine.

7.4.3 Method of Data Collection

Two perpendicular lines of surveyed markers will be estabished on the surface overlying the initial excavated mine area. This survey will extend to outer limits of probable draw angle (usually 45°) from mine level to surface. One survey line will be oriented parallel to the mine entries and the remaining line will be perpendicular. The markers will be laid out approximately 300 feet apart and will extend off-site beyond the area of mining development. The survey lines will be set up in advance of mining to determine initial surface elevation.

7.5 Hazardous Waste Monitoring

The WRSOC plans to dispose of hazardous waste materials from all phases of the WRSP on-tract. The hazardous waste landfill will be sited so as to take advantage of natural topography. A comprehensive field and geotechnical investigation is planned to describe bedrock units, structural characteristics, surficial deposits, and other factors critical to the location of a hazardous waste disposal facility. The facility will be located in a side canyon which receives a minimal amount of runoff from adjacent slopes. The location of the canyon, relative to inhabited plant buildings, will be such that wind dispersal of waste (prior to covering) in the direction of the plant is minimized.

It is anticipated that the landfill will be up to 40 feet in depth and cover up to six acres surface area at final configuration. The landfill will be designed to prevent releases from the area into the land, surface water, and ground water. Prior to site closure, any leachate will be intercepted and collected in a retention pond immediately downgradient of the landfill. The entire system will be lined.

7.5.1 Program Design and Rationale

This hazardous waste monitoring program is designed to detect ignitable, corrosive, reactive, toxic or similar substances (hazardous materials) in the environment that originated from within the proposed hazardous waste disposal facility. Although the facility will be designed to prevent discharge, there is a potential that such compounds used in and/or generated by facility operations and processes could contaminate surface water resources or migrate toward the underlying ground water system after being placed within the landfill. Early detection of such occurrences will allow implementation of the appropriate mitigation measures which are aimed at preventing the degradation of existing surface and ground water quality.

The principal objectives of the hazardous waste monitoring program are to ensure 1) the protection of human health and the environment from potential adverse project-related impacts, and 2) preservation of existing environmental conditions. These objectives are attained through implementation of and strict adherence to all currently applicable and anticipated RCRA/EPA monitoring requirements and operational guidelines. The monitoring program is designed to satisfy, and in some cases exceed, the terms and intent of regulatory compliance by 1) meeting all anticipated monitoring requirements and 2) documenting all appropriate operational procedures related to potential accidental discharges of hazardous waste constituents.

7.5.2 Parameters to be Studied

The hazardous waste monitoring program will collect and maintain the following types of data relating to disposal operations. Accompanying each category is a brief rationale for inclusion in the program.

- Quality of leachate and contaminated runoff: to determine the chemical nature of potential contaminants which may be accidentally released from the disposal area;

- Volume of leachate and contaminated runoff: to quantify the potential volumetric impacts of contaminated water released to the surface and subsurface environment;

- Rate of migration of subsurface leachates: to estimate potential volumetric and areal impacts related to subsurface contamination, and to provide information for contingency planning.

In addition, the following monitoring categories are included in this program to coincide with efforts involved in other disciplines. The integrated program involving hydrology and meteorology will provide

data for establishing compliance with certain hazardous waste monitoring requirements and operational guidelines:

- o Ground water quality and flow direction in the uppermost aquifer: to identify and quantify potential project-related impacts on the underlying aquifer;

- o Local climatic conditions (rainfall, wind and evaporation): to document the effects of local precipitation and winds. Also, a decline in impounded water levels which exceed that predicted to be lost by evaporation could indicate seepage of water from collection/retention devices.

Water quality parameters for leachates, runoff, and ground water monitoring are based on recommended parameters for existing hazardous waste landfills and surface impoundments as described in 40 CFR 265.92. They are:

(for ground water quality) -	Chloride
	Iron
	Manganese
	Phenols
	Sodium
	Sulfate
(for ground water comtamination) -	pH
	Specific Conductance
	Total Organic Carbon
	Total Organic Halogen

Arsenic and chromium will also be monitored because EPA interim primary drinking water standards have been established for these elements (40 CFR 265, App III) and they are known to exist in anticipated process wastes. Data concerning the chemical quality of impounded waters will be useful in identifying the character of potential seepage from retention devices.

7.5.3 Sampling Locations and Schedule

Ground Water

A total of four ground water sampling/monitoring wells (piezometers or lysimeters) will be installed in the alluvium directly above the alluvium-bedrock interface that underlies the perimeter of the waste disposal area. These wells will be placed along or near the axis of the canyon containing the disposal area. One well will be installed immediately upgradient of the final landfill boundary. Two wells will be installed slightly below the downgradient end of the landfill between the disposal area boundary and a cutoff wall (if such a barrier is included in final design plans). The remaining well will be installed below the cutoff wall to monitor potential underflow. Exact monitoring locations will depend on final landfill design and detailed hydrogeologic data developed during drilling and installation.

Monitoring will begin on a quarterly basis during the first year for the ground water contamination indicators (pH, EC, TOC, TOH) during this year. Sampling and analysis will continue on a semi-annual basis after the first year for all ground water quality parameters noted above.

Surface Water

Surface water sampling will be conducted in the leachate and runoff collection/retention devices adjacent to the fill area. Samples will be drawn opportunistically from all impoundments containing significant quantities of fluids originating within the disposal area. This will occur primarily during and immediately following significant rainfall events and during times when leachate generation and seepage may be high. The opportunistic sampling interval will be dependent upon precipitation rate and duration, local infiltration and evaporation rates, runoff drainage area, leachate generation and percolation rates.

The quantity of liquids contained within collection and retention structures will be monitored in conjunction with surface water sampling. At the time surface water samples of impounded precipitation, runoff, and leachates are taken, an estimate will be made of the total volume of these impounded liquids, and the amount of remaining impoundment capacity (freeboard) will be determined for all retention devices. This will be accomplished by using staff gauges in these locations.

Although final design plans have not been completed for the disposal area collection/retention system, all such structures as proposed in the final plans will be monitored. This will involve inspection of all dikes, berms, culverts, trench drains, embankments, impoundments, sumps, collection basins, and similar surface devices. All precipitation, runoff, and leachate collection/retention devices will be monitored by visual examination in accordance with a routine inspection and maintenance schedule.

7.5.4 Methods of Data Collection

The ground water monitoring system will consist of several lysimeters or piezometers installed in the site alluvium near the proposed disposal area. Samples will be recovered from the monitor wells by submersible pump, air lift, bailer, or other suitable means at specified intervals. Preservation, transportation and analysis of samples will be in conformance with the references cited above, other accepted documents, and standard ground water monitoring practice.

Surface water samples will be drawn from hazardous waste area collection/retention devices by siphon, suction pump, or other acceptable methods. The handling, treatment, transport and analysis of collected water samples will be similar or identical to procedures utilized for ground water samples.

7.6 Sediment Characterization Study

7.6.1 Program Design and Rationale

The transport of adsorbed compounds by sediments is a major mechanism by which organic and inorganic soil constituents enter and are dispersed in rivers and streams. This may occur when these materials are transported by clay particles entering streams via wind and surface erosion from the tract. Data collected from the sediment characterization study will define the potential for sediment transport of adsorbed constituents from natural and project-related activities.

The basic physical and chemical characteristics within the stream and dry wash areas will be determined. This study will analyze sediment particle size distribution, and the concentration of geochemical constituents in the solid phase, including major, minor, and trace elements.

If potentially harmful concentrations of a substance are found in the sediments, the sources of the material will be investigated. Tests will then be conducted to determine the levels of that substance in exposed bed material that result from project-related activities.

7.6.2 Parameters to be Studied

Currently, studies being conducted on other federal lease tracts by USGS and others include the following characteristics of sediments:

- grain size (screen analysis to a minimum of seven fractions)
- mineralogic examination (microscopic)
- x-ray diffraction (bulk sediment and clay mineral chemistry)
- spectroscopic analysis (trace metals)
- cation exchange capacity

The object of these studies is to determine which parameters are significant in interpretation and practicable to include in a monitoring program.

WRSOC will make use of these results and other existing site-specific data such as mineralogy, suspended sediment concentrations, and particle size distribution to determine the final list of parameters to be studied. It is expected that the WRSP studies will consist of an examination and analysis for:

- o sediment size distribution
- o x-ray diffraction
- o spectroscopy, for adsorbed material
- o cation exchange capacity

This list will be reviewed and finalized in consultation with the OSO.

7.6.3 Methods

The samples for the sediment characterization will be collected annually (low flow period) at the following gauging stations:

- o White River: 09306700
- o Evacuation Creek: 09306430
- o Southam Canyon: 09306610
- o Plant site drainage: 09306602

Collection of sediment characterization samples will be coordinated with water quality and suspended sediment sampling periods. A composite sample of sediment collected by using a BMH-53 sediment sampler or equivalent will be prepared by combining several individual samples. A minimum of six individual samples taken at uniformly-spaced intervals across the stream will be collected for each composite sample.

Sediment characterization data will be compared with available baseline soil and sediment information. If potentially harmful concentrations of a substance are found in the sediments, the sources of the material (e.g. project soils or subsoils) will be investigated. Tests will be conducted to determine the levels of that substance in site materials exposed by tract-related activities.

7.7 Raw Shale Leachate Studies

At the present time, the Colorado prototype oil shale tracts Ca and Cb are involved in a program to evaluate the quality of leachate from their run-of-mine shale storage piles. These studies are being undertaken in cooperation with several federal and university participants.

These studies have indicated that raw shale leachate contains dissolved solids at elevated concentrations relative to the background. However, these tests are being conducted under climatic conditions which are measurably different than those occurring over Ua and Ub. Thus, it can be expected that the results of such a study in Utah would yield information different from that being collected in Colorado. Generally, it can be expected that with lower annual precipitation and higher evaporation rates, the Ua/Ub raw shale leachates will occur in lower volumes and generally be elevated from normal background levels.

Thus, it is planned to monitor and evaluate the methodology and results of the Colorado tests and then to design a raw shale leachate program which best suits Ua/Ub conditions. The details and extent of the program will be developed in consultation with, and will be approved by, the OSO prior to initiation. Further, since raw shale will not be available from the Ua/Ub mine for several years, our program design will not be deveoped at this time.

8.0 ECOSYSTEM ANALYSIS

The goals of the environmental monitoring program for the WRSP are impact and pathway identification. To accomplish these goals, the monitoring program uses logic to identify potential impacts, detect actual impacts, and to identify possible pathways. Parameters are selected and ranked objectively using those which are ecologically important and which lie along the expected pathways. Sample site locations are tailored to anticipated impacts and have a statistical and ecological basis for their selection. The program also contains decision criteria, that is, a rationale for identification of impacts which invokes contingency measures when a change is quantified.

A conceptual description of the Ua/Ub ecosystem was employed to identify and monitor important components of the ecosystem. This conceptual description is not a simulation model which predits outputs given inputs. Rather, it is a logical "picture" of the components and processes occurring in the ecosystem based upon the literature and WRSP site-specific data. This allows us to develop quantitative relationships which are important in documenting project-related change.

This approach recognizes that the biological components of the tracts exist within, and interact with, the physical environment (including air quality, meteorology, water quality, and geology as shown in Figure 8.0-1) and provide a means for identifying important impacts and tracing their pathway. The biological components consisting of producer, consumer, and decomposers have dominant characteristics such as structure (taxonomic groups, biomass), function (trophic interrelationships) and rate processs which vary with geographic location and time (Figure 8.0-2). These are important aspects of an integrated monitoring program.

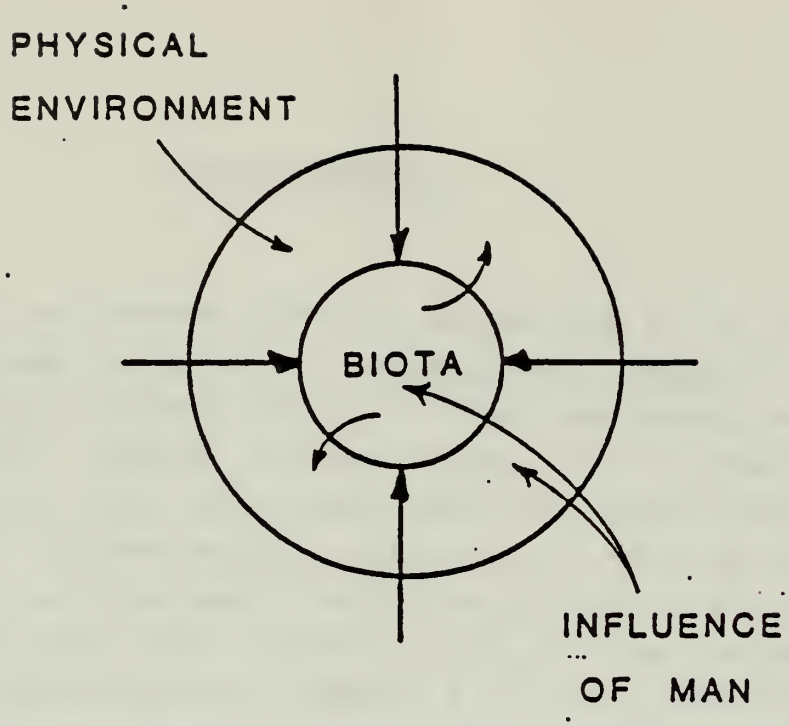


Figure 8.0-1. Conceptual view of the interaction of the physical and biological components of the ecosystem indicating the influence of man.

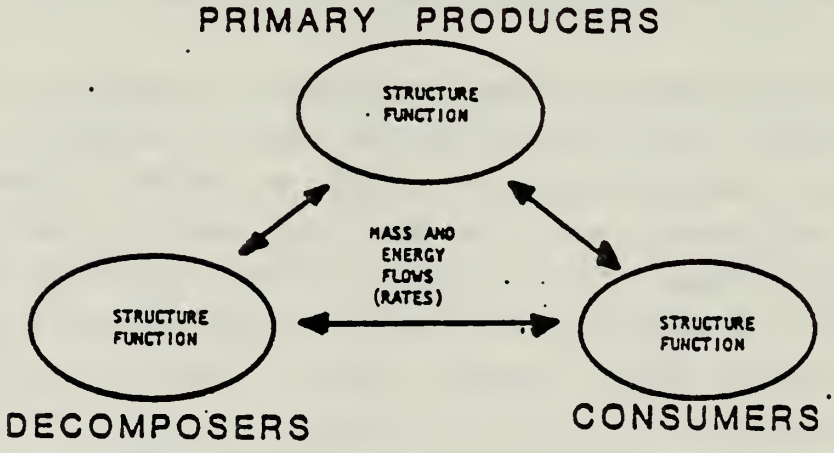


Figure 8.0-2. Interactions between the biological components of the ecosystem.

Superimposed upon this view of a naturally-evolving environment is the proposed development of Tracts Ua and Ub. The WRSP through its planned construction and operation activities can directly or indirectly affect both the physical and biological systems.

In many cases a significant change in an environmental parameter can be documented using data from a single discipline. However, because of natural variability, it is often difficult to identify the true pathway or mechanism that results in an environmental impact. Thus, there is a need for "ecosystem analysis" that integrates data from each discipline into a holistic picture of the environment. This will allow quantitative assessment of change by recognizing cause and effect which is manifested through a series of interrelationships.

Each discipline has its own structural (static) and functional (dynamic) parameters which are viable for detecting change in that particular discipline. But, the quantitative interrelationships described in this chapter recognize the dynamic nature of the system and allow statistical tests to be performed which can lead to the probable cause of an adverse impact.

A computerized data management system is used to systematically evaluate monitoring parameter relationships and to identify environmental changes. This system, identified as MONITOR, is described in Section 8.4. Although many relationships between parameters can be mathematically derived, only relatively few are useful for evaluating ecosystem changes. Previously collected Ua/Ub environmental data, together with a conceptual understanding of tract ecosystems, allow the identification of meaningful site-specific relationships. Sections 8.1 and 8.2 describe the aquatic and terrestrial ecosystems in terms of these relationships. Environmental impacts are identified based on these quantified relationships, multi-level detection logic and statistical analyses. Section 8.3 describes impact identification and statistical consideration procedures.

8.1 The Terrestrial Ecosystem

Tracts Ua and Ub lie in the Uinta Basin, a region that can best be described ecologically as a cold desert. These areas are generally characterized by: 1) northern location (above 37°N latitude); 2) high elevation; 3) low winter temperatures; 4) precipitation input predominantly during winter in the form of snow, and 5) irregular summer precipitation. These properties, combine to produce a unique biota that is more diverse than other desert areas. The following discussion will briefly describe the key abiotic and biotic components and interrelationships of the terrestrial ecosystem.

8.1.1 Abiotic Factors

The primary abiotic factors which affect the terrestrial biota on Tracts Ua and Ub are climate and physiographic and edaphic factors. Temperature and precipitation interact with air quality and site conditions (soils, parent material slope, slope position, aspect, macro- and micro-climatic relief) to determine the floral and faunal patterns of distribution on Tracts Ua and Ub.

Climatology

Climatology is a major determinant of ecosystem structure and function on Tracts Ua and Ub. This area is characterized by large temporal fluctuations in precipitation, great extremes in temperature, and a moderately xeric environment. In addition, wind may be an important factor in the physical transfer of nutrients into and out of the ecosystem.

During the seven-year baseline and preconstruction period, precipitation on the tracts has varied between 6.2 and 11.2 inches/year (15 and 27 cm/yr). Precipitation varies over time and between locations within the tracts due to the varied terrain and intense, isolated

thunderstorms that cross the region. Temperatures varied between extremes of -22°F (-30°C) and 97°F (36°C) during the years 1975 to 1980. Diurnal variations in temperature average 48°F (9°C) during January and 63°F (17°C) during July. Relative humidity is generally maximum in winter (80%) and minimum during summer (25%). Total evaporation during the frost-free period May-September averaged 37.6 inches (94 cm) (DDP 1981).

Wind speed and direction over the tracts is highly variable temporally and topographically, but patterns of flow do exist. These patterns include a general westerly trend of flow with nighttime cold air drainge flow to the White River and daytime upslope flow during afternoon hours. Surface inversions occur in the mornings and dissipate in the afternoon. The strength of inversion varies with season, with the strongest inversions occurring in the winter. These flow patterns will interact with air pollutant emissions such as sulfur dioxide, nitrous oxides, carbon monoxide, hydrocarbons, and particulate matter to create localized concentrations during plant operation. Air quality measurements for these parameters (and others) have been made since 1975. With the exception of ozone, and to a lesser degree particulate matter, these constituents occur in low concentrations near the threshold of detection.

Soils

The climate and geology of the area influence the formation and composition of soils on Tract Ua and Ub. For example, during short periods of soil wetness, chemical weathering can proceed rapidly. On Tracts Ua and Ub, soil moisture is the major limiting resource for plants. Moreover, soil moisture is affected by soil composition which is the major factor influencing: (1) the frequency and rate at which water stores are filled; (2) the capacity of these stores; (3) the rate at which they are emptied by evaporation and transpiration, and (4) the energy needed by plants to reach and use them (Noy-Meir 1973). The

major structural and compositional features of a soil affecting water stores and their use are: 1) the relative proportions of sand, silt, and clay; 2) the size and proportion of coarse mineral fragments; 3) the organic matter content, pore size; 4) the types of clay present; 5) presence of carbonates or other accumulated salts; 6) the cation exchange capacity; 7) the exchangeable sodium percentage; 8) the total soluble salt content, and 9) slope aspect, i.e. south-facing slopes retain less moisture than north-facing slopes (Slater et al 1966, Alizai and Hulbert 1970, Fuller 1974, Donahue et al 1977) (Table 8.1-1). Soil moisture is also affected by soil horizon depths, position on slope, percent slope, aspect and shading by physiographic structures.

8.1.2 Biotic Factors

The biotic community (vegetation and wildlife) responds to physical factors, such as soil type or soil moisture and other physical factors discussed previously, and to a variety of biotic factors as well.

Vegetation

Algae (predominantly Cyanophyta and Chlorophyta) and lichens, frequently found in the surface of these desert soils, have the capacity for photosynthetic activity and rapid growth from even the most transient wetting of the soil. Annuals and herbaceous perennials take up most of their moisture from the 10-30 cm layer of soil, although once established their roots may penetrate deeper (Noy-Meir 1973). Shrubs maintain deep root systems in layers of soil only slightly affected by evaporation, although they may also maintain an extensive horizontal network of roots close to the surface to take advantage of intense but short summer rains. These deep soil layers can lose moisture from evaportranspiration of shrubs and other deep-rooted vegetation.

TABLE 8.1-1

CHARACTERISTICS OF THE THREE PREDOMINANT
SOIL TYPES ON THE OIL SHALE TRACTS

Characteristic	Soil Type		
	Deep Soil	Shallow Soil	Deep Alluvium Soil
Depth to Bedrock (cm)	150+	5-50	150+
Water Capacity Available (cm/cm)	0.30-0.36	<0.25-0.28	0.36-0.41
pH	7.9-8.3	7.5-8.7	8.1-8.9
Electrical Conductivity (mmhos/cm)	1.0-19.0	0.3-6.0	5.0-15.0
Runoff Potential (cm/ha)	6.1	3.6	0.8
Organic Content (%)	0.4-0.5	0.5-1.2	0.2-1.4
General Classification	Ds, E	A,B,F	W,N

Source: DDP 1981.

The upland vegetation on Tracts Ua and Ub is typically composed of a shrub overstory with an understory of herbaceous and graminoid perennials and annuals. The vegetation associations occurring on the tracts are dominated by four major types (WRSP 1981). These are Sagebrush-greasewood, Juniper, Shadscale and Riparian types. The distribution of these four types is influenced by soil moisture, composition, and topography which are a result of climatic, geologic, and weathering processes.

Vertebrates

Birds are the most diverse vertebrate group on the tracts comprising 138 species. However, only 43% of these species occurred consistently over a seven-year period. Seasonal use of the tracts is highest from April through August when the summer residents are at their peak. Permanent residents constitute only 16 species, whereas summer residents are represented by 65 species. Transients/migrants occur at low abundance and are represented by 48 species.

Invertebrates

In addition to vertebrates, soil and foliage invertebrates and microbes also occur on the tracts. The diversity and density of these populations is lower than in more mesic environments, but their importance in decomposition and nutrient cycling, and therefore primary production, is nonetheless very important. The abundance and distribution of microorganisms in the soils is closely associated with quantity and distribution of organic carbon in the soil that they use as an energy source. Organic carbon in the soils is supplied primarily from plant litter, although dead animals and microorganisms may make a substantial contribution. The baseline program showed that microorganisms generally were concentrated near the soil surface where supplies of oxygen, water, and organic carbon were greater.

Table 8.1-2. Composition of vegetation associations and relationship to soil types.

Vegetation Association	Major Soil Type [1]	Dominant Shrubs or tree	Dominant Perennials	Dominant Annuals
Sagebrush greasewood	Deep soils along valley and canyon bottoms "D"	Artemesia tridentata (Big sagebrush) Sarcobatus vermiculatus (Greasewood) Atriplex confertifolia (Shadscale)	Oryzopsis hymenoides (Indian ricegrass) Stipa comata (Needle-and-thread grass) Hilaria jamesii (Galleta grass)	Bromus techtorum (Cheatgrass) Salsola kali (Russian thistle) Halogeton glomeratus (Halogeton)
Shadscale	Shallow soils in eastern uplands and river terraces "A, As, B, Bs, F, E, N"	Atriplex confertifolia Artemisia tridentata	Oryzopsis hymenoides	Bromus tectorum Salsola kali Halogeton glomeratus Chorispora tenella (Blue mustard)
Juniper	Shallow, rocky soils at high elevations (1600 m) "As, R, Bs"	Juniperus osteosperma (Utah juniper) Artemisia nova (Black sagebrush) Atriplex confertifolia	Oryzopsis hymenoides Hilaria jamesii	Lepidium montanum (Pepper grass) Bromus tectorum
Riparian	Deep alluvia soils along White River and Evacuation Creek "W"	Populus fremontii (Cottonwood) Tamarix pentandra (Salt cedar) Chrysothamnus spp. (Rabbitbrush)	Distichlis stricta (Saltgrass)	Bromus tectorum Lepidium montanum

[1] See Final Environment Baseline Report, 1977, for detailed soil physical and chemical description

8.1.3 Abiotic Influences on Biota

The abiotic influences on biota include three major categories: influences on primary producers, consumers and decomposers.

Abiotic Influences on Primary Producers

The four major plant associations occurring on the tracts respond to soil type (structure) and climatic processes (Table 8.1-2). Most of the annual plants mature in early spring when soil moisture is high and temperatures moderate. The tract-wide annual plant biomass measured in June responds to spring precipitation according to the relationship shown in Figure 8.1-1. Perennial plant production as reflected by sagebrush stem leader growth responds to the previous year's fall and winter precipitation according to the relationship shown in Figure 8.1-2. Thus, while soil structure and chemistry appear to determine structural components of the various plant associations, moisture input coupled with the moisture holding capacity of the soil influences plant production in a highly predictable manner. These relationships by their integration of physical and biological parameters become valuable tools for detection of impacts and impact pathways.

Abiotic Influences on Consumers

The consumer, or animal community on the tracts consists of the birds, mammals, reptiles and above-ground invertebrates. Although precipitation per se may not be a critical factor in determining consumer activity and distribution, the effects of precipitation are extremely important because of its influence on primary production. Temperature is also an important factor to both endotherms (mainly affecting their water balance) and ectotherms (affecting their activity) (Porter et al 1973). Temperature regulation is maintained by avoidance of high temperature during nocturnal activity periods, extensive use of shade provided by shrubs, and use of burrows in the soil (Low 1979).

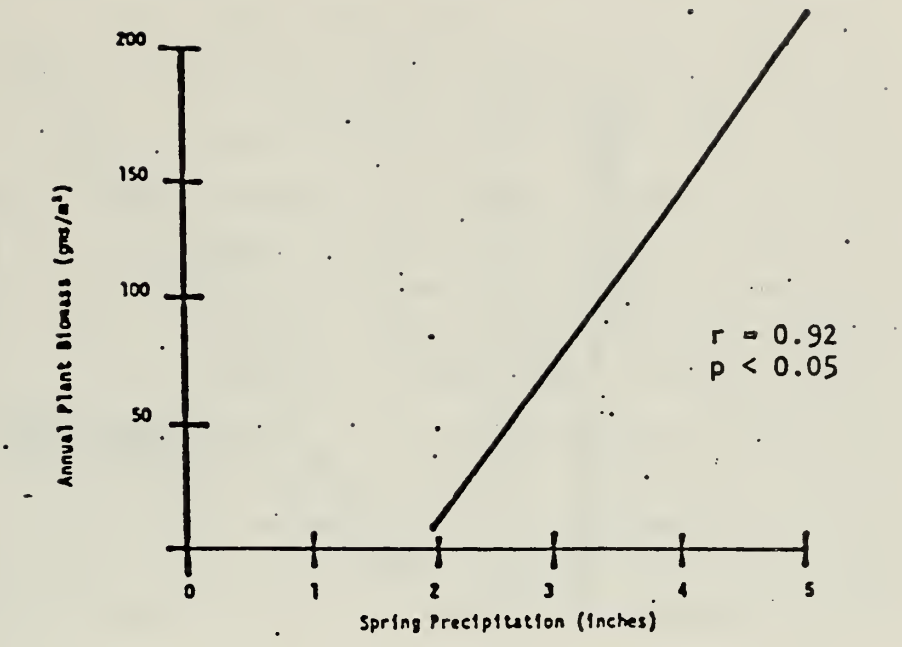


FIGURE 8.1-1 ANNUAL PLANT GROWTH VS. SPRING PRECIPITATION

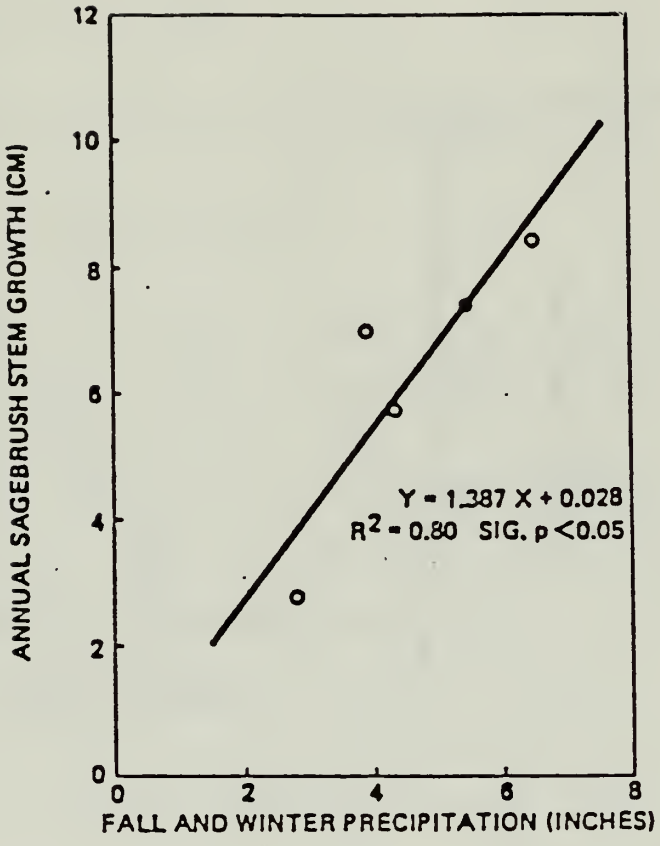


Figure 8.1-2. Mean annual sagebrush stem growth related to fall-winter precipitation.

Note: Mean annual sagebrush stem leader growth is used as an index of perennial plant growth. This relationship is being validated for other shrub species in the on-going monitoring program.

Soil conditions such as soil slope, color, depth, texture and moisture are extremely important to the majority of small burrowing mammals. These parameters have all been implicated in the distribution of rodents, by presumably affecting soil cohesion, and burrow temperature and humidity which are of vital importance to burrowing rodents (Hardy 1945, Fautin 1946, Chiselin 1970, Low 1979) (see Figure 8.1-3). This has been shown by rodent abundance and diversity on Tracts Ua and Ub which correlate well with substrate type. Other similar effects have been documented in the literature. For example, a positive correlation was also found between many desert reptiles and arthropods and the presence of surface sand (MacMahon and Wagner 1980). Similarly, reptile abundance has been shown to vary with temperature (seasonally and diurnally) and substrate type on Tracts Ua and Ub. Soil conditions, such as organic matter and soil moisture, have been shown to be strongly related to the distribution of soil arthropods (Wallwork 1972, Santos et al 1978, Franco et al 1979, Whitford and Ettershank 1974).

Abiotic factors can also influence the abundance and distribution of insects on the tracts. In particular, the dominant functional group, the phytophagous insects (those deriving nutrition from plants) peak in abundance during June when not only plant production but, climatic factors, such as temperature and moisture, are most favorable. This relationship to climatic factors will be important in documenting pathways of environmental effects.

The vertebrates (birds and mammals) inhabiting the tracts are dependent upon water resources and primary production (plant growth). These animals exhibit a variety of adaptations to cope with a limited water supply, sub-freezing temperatures in winter and high temperatures in summer. Of prime importance is the mobility of the vertebrates which allows them to take advantage of environmental differences in moisture and temperature (Noy-Meir 1974). The data collected on Tracts Ua and Ub have shown predictable patterns of vertebrate abundance and diversity in relation to moisture, soils and vegetation types (WRSP 1981).

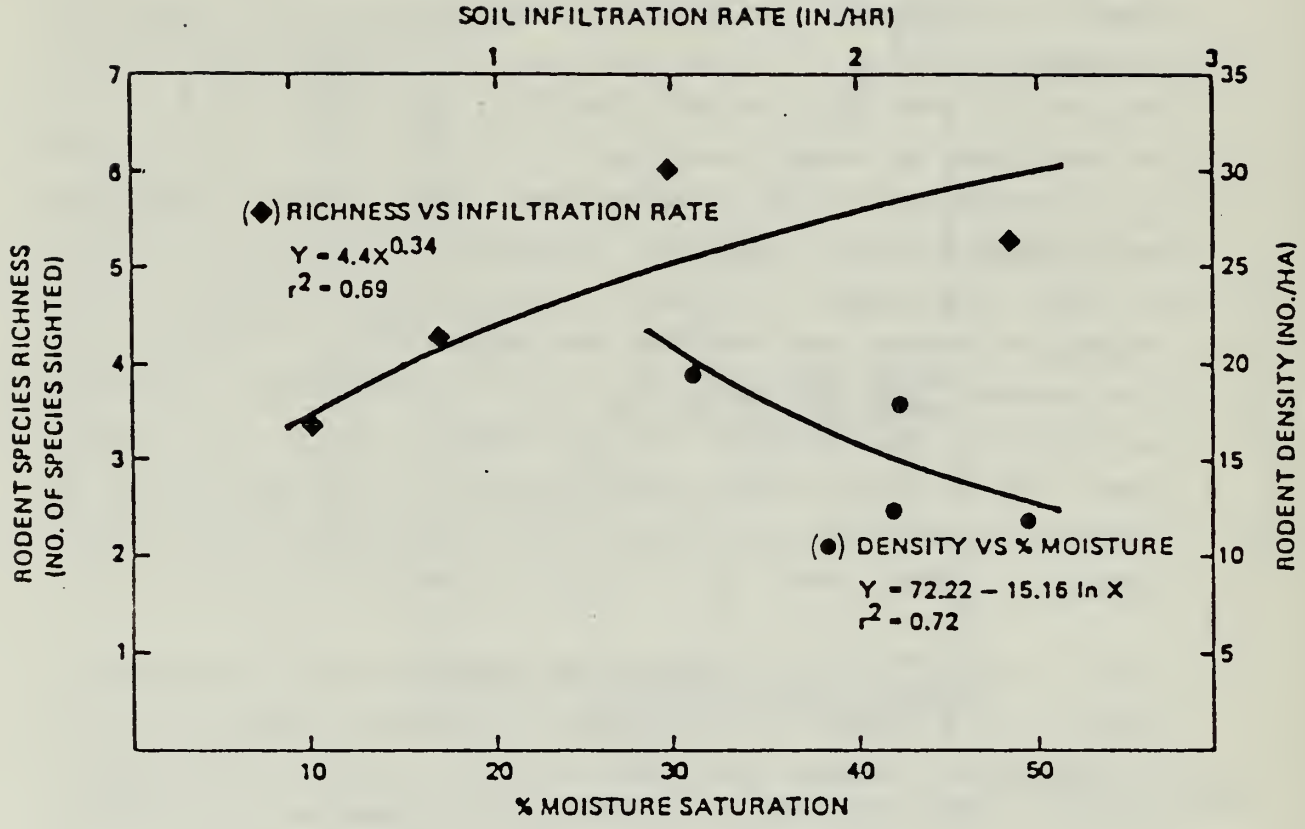


Figure 8.1-3. Response of rodent species richness and density to soil factors.

It is also possible for consumers to influence abiotic factors. For example, through their burrowing activities, small rodents mix and aerate the soil, increase water infiltration, and by their feces and storage of plant material increase the quantity of organic matter and important nutrients (Fautin 1945, Noy-Meir 1974, Soholt et al 1975, El-Ayouty et al 1978). Such changes in soil conditions also promote the activity of microbial organisms that are important in decomposition and nutrient cycling. It has also been shown that livestock grazing increased soil compaction with many adverse consequences (Webb and Stielstra 1979, MacMahon and Wagner 1980). Similarly, invertebrates have also been shown to have an impact on soil mixing (Noy-Meir 1974), soil structure (Hugie and Passey 1963), and soil chemical composition (Noy-Meir 1974, El-Ayouty et al 1978). It is also possible that desert detritivoric arthropods have an important role in nutrient cycling (Noy-Meir 1974, Ward 1976, Crawford 1979).

Abiotic Influences on Decomposers

Decomposition is a physical and chemical process of: 1) comminution, the physical reduction in particle size of organic matter brought about by the feeding of decomposer organisms, trampling by large vertebrates, or abiotically by freeze-thaw or wet-dry cycles; 2) leaching, an abiotic process in which water removes the water-soluble matter from detritus, and 3) catabolism, an enzymatic reaction by decomposers which transforms or breaks down complex organic compounds into smaller and simpler molecules. These three processes act simultaneously and are interactive (for example, comminution increases the surface area of a detritus particle to catabolic enzymes and also increases the accessibility to water for leaching). The major organisms involved in decomposition are the soil invertebrtes (nematodes and arthropods), bacteria and fungi. The soil arthropods are important in comminution while the nematodes accelerate nutrient cycling by grazing the bacterial populations. The bacteria and fungi are involved in the catabolism of organics.

Given adequate organic resources, it has been shown that temperature, moisture, and substrate are dominant factors determining spatial and temporal distributions of populations. For example, arthropods and nematodes are abundant during periods of moderate temperature and moisture. It is expected that additional quantified relationships will be generated for these groups between temperature, moisture and soil particle size (Dr. Lloyd Bennett, verbal communication).

Soil moisture and soil organic content are extremely important abiotic factors that affect the activity of soil microbes measured on the tracts during the baseline period (Table 8.1-3). Physical soil factors such as grain size and salinity play an important role in regulating organic content and available water for the microbes.

8.1.4 Biotic Interactions

The relationships between the producers, consumers and decomposers are extremely important in determining the pathway of an impact. Certain dominant factors are apparent based on data collected for Tracts Ua and Ub. For example, the structural diversity and productivity of the plant community reflects soil composition and climatic input and subsequently drives the dynamics of the animal communities. Moreover, the foliage structure of the plant community explains many habitat variations in the bird and rodent community diversity and richness (Table 8.1-3). Production in these animal communities is however, closely tied to the production of the plant community (Figures 8.1-4 and 8.1-5). These relationships will be valuable in tracing pathways, particularly when the biota are divided into functional groups based upon food source (i.e., granivore, insectivore, etc.). In other words, bird population changes may be explained by changes in a single functional group, thus indicating the possible pathway of an impact through the food chain.

TABLE 8.1-3

IMPORTANT INTERRELATIONSHIPS ESTABLISHED FOR THE TERRESTRIAL SYSTEM OF TRACTS UA AND UB. All CORRELATIONS (r) ARE SIGNIFICANT AT $p < 0.05$. (EQUATIONS BASED ON UA/UB DATA: LITERATURE CITATIONS PROVIDE VALIDATION FOR GENERAL EQUATION)

	Equation	(r)	Literature Citation
Decomposer Interrelationships (biotic-abiotic)			
1. Dehydrogenase Activities (y) vs Organic Carbon (x)	$y = 16.2x - 2.48$	0.67	Skujins 1976 West and Skujins 1977
2. Proteolytic Activity (y) vs Organic Carbon (x)	$y = 10.7x + 4.44$	0.66	Skujins 1976
3. Respiration (y) vs Soil Moisture (x)	$y = 1.19x + 1.83$	0.66	Skujins 1976, 1979
Primary Producer Interrelationships (biotic - abiotic)			
1. Annual Plant Production (y) vs Spring Precipitation (x)	$7 = 306x - 567$	0.92	Fischer and Turner 1978
2. Perennial Plant Production (y) vs Fall-Winter Precipitation (x)	$y = 1.38x - 0.03$	0.89	Fischer and Turner 1978
Consumer Interrelationships (biotic - abiotic)			
1. Breeding Bird Biomass (y) vs Spring Precipitation (x)	$y = 78.7x + 3.14$	0.88	Cody 1981
2. Annual Bird Abundance (y) vs Annual Precipitation (x)	$y = 2.62x - 3.26$	0.83	Cody 1981

TABLE 8.1-3 (cont.)

	Equation	(r)	Literature Citation
Consumer Interrelationships (biotic - abiotic) (cont.)			
3. Reptile Abundance (y) vs Percent Bare Ground (x)	y = 5.17x + 22.2	0.88	
4. Cliff Swallow Density (y) vs Maximum Spring Streamflow (x)	y = 0.032x - 32.89	0.77	
Decomposer Interrelationships (biotic - abiotic)			
1. Proteolytic Activity (y) vs Streptomycetes Populations (x)	y = 0.45x + 7.39	0.45	
2. Proteolytic Activity (y) vs Fungi Population	y = 2.37x + 7.67	0.56	
3. Repiration (y) vs Aerobic Bacteria Population (x)	y = 2.07x + 7.49	0.54	
Consumer Interrelationships (biotic-abiotic)			
1. Breeding Bird Biomass (y) vs Annual Plant Production (x)	y = 2.32x + 703	0.73	
2. Breeding Bird Species (y) vs Foliage Height Diversity (x)	y = 12.2x +12	0.92	Balda 1975
3. Breeding Insectivorous Bird Abundance (y) vs Foliage Invertebrate Biomass (x)	y = 60.7x + 7.79	0.97	Cody 1981

TABLE 8.1-3 (cont.)

	Equation	(r)	Literature Citation
Consumer Interrelationships (biotic-abiotic) (cont.)			
4. Small Mammal (Cricetic) Density (z) vs Annual Plant Production (y) vs Perennial Plant Production (x)	$z = 0.014y + 0.132x + 3.168$	0.97	Beatley 1976
5. Hawk Abundance (*Buteo jamaicensis*) (y) vs Cottontail Abundance (x)	$y = 0.013x + 0.013x$	0.88	
6. Shrike (Lanius) Density (y) vs Cricetic Density (x)	$y = 0.089x + 0.11$	0.87	

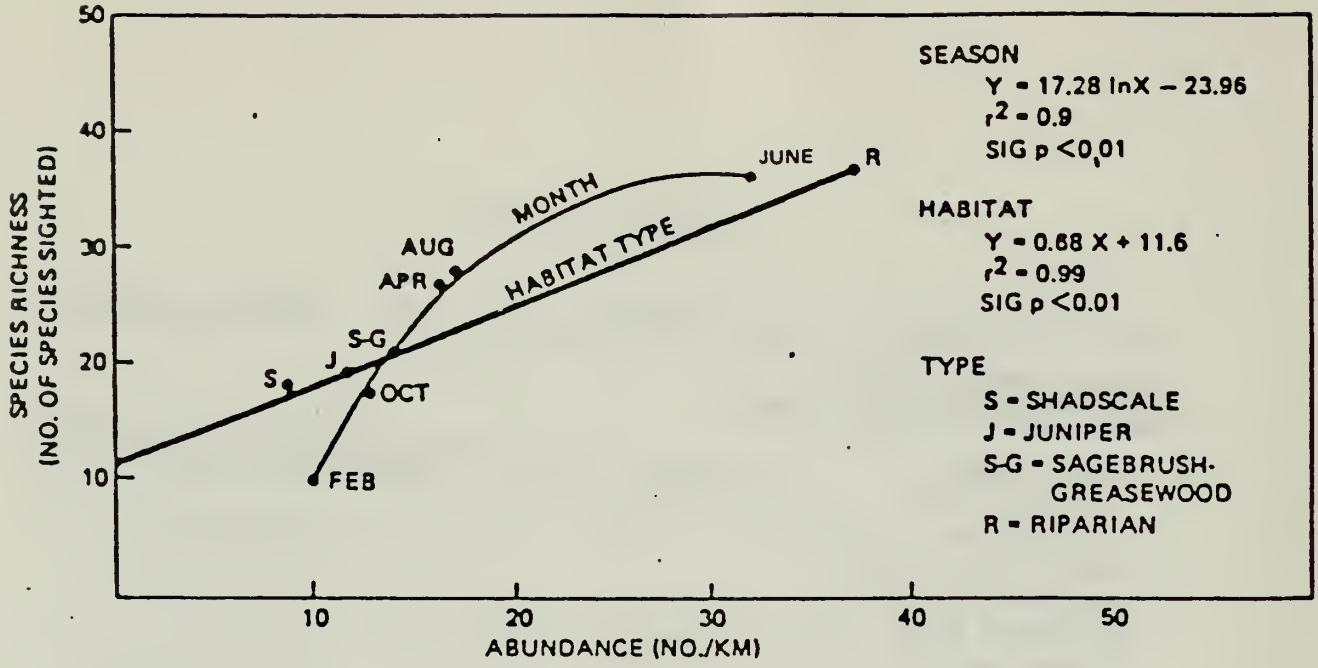


FIGURE 8.1-4 Mean annual and monthly bird species richness and abundance for the four habitat types, 1975 to 1979.

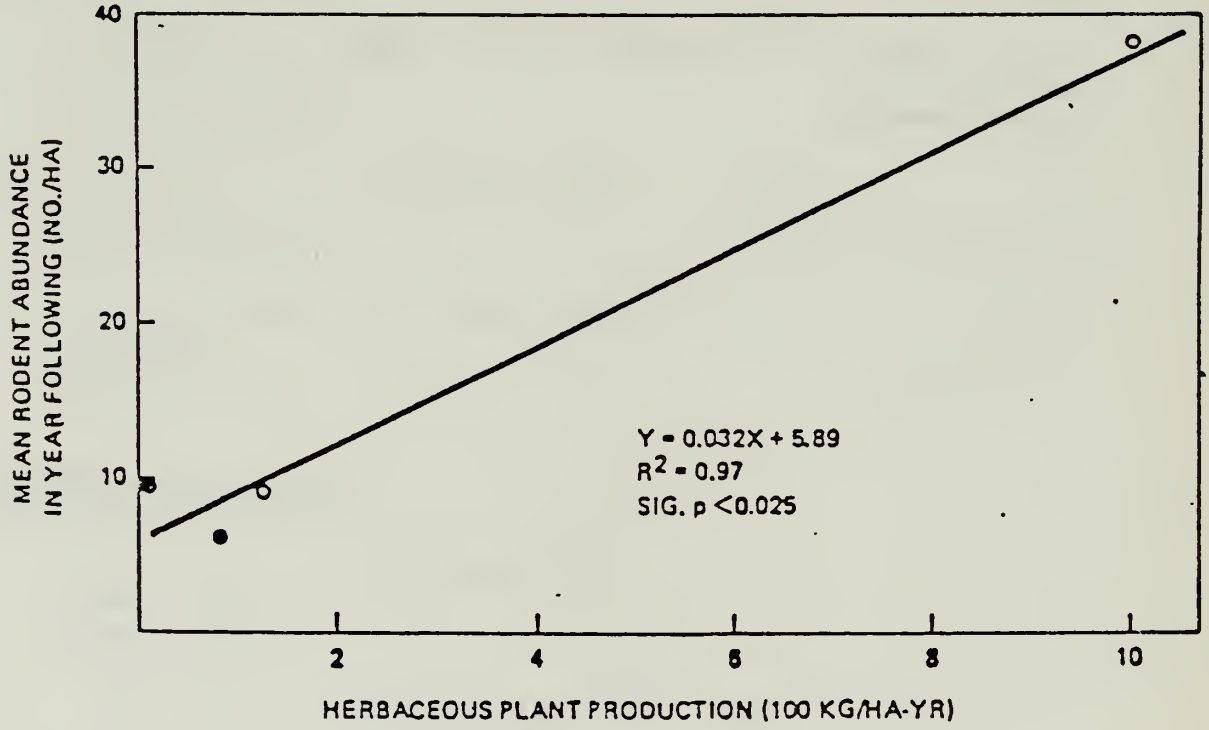


FIGURE 8.1-5 Mean rodent abundance related to mean herbaceous plant production (precipitation of a given year is compared to the following year's rodent abundance).

The invertebrate consumers production dominated by the phytophagous species (herbivores) are closely tied to the production of the plant community. During one year of data collection (1981) these populations peaked in the early summer and fall seasons. These are periods when annual plant and shrub production are maximum and temperature and moisture conditions are favorable. As the populations of these invertebrates track physical and biological processes, the organisms that feed upon them are expected to show similar patterns, thus establishing another set of relationships which can trace pathways.

The dynamics of the decomposers are reflective of organic input (litter fall) from the plant community and are important because the soil microbial community could be rapidly affected by leachate and air quality changes. Changes in these relationships can be quickly detected using microbial activity patterns because of the short generation time of these organisms. By having established quantitative relationships between the microbes and their environment, documentation of whether change is natural or industry-related and the tracing of potential pathways may be accomplished.

The foregoing discussion represents only a small portion of the observed and expected relationships occurring in the terrestrial ecosystem of the oil shale tracts. A sampling of representative relationships found to date were previously presented in Table 8.1-3. Those expected to occur are presented in Table 8.1-4. All of these quantified relationships will be employed in "MONITOR" (see Section 8.4) to detect departures from expected and elucidated pathways.

8.2 Aquatic Ecosystem

The White River ecosystem near Tracts Ua and Ub can be described in terms of a discrete stream segment which exists as a part of a much larger stream continuum that originates at the headwaters and ends at the point of discharge. Abiotic climatic factors influence the river

Table 8.1-4. Expected terrestrial interrelationships which might be important in pathway analysis and impact detection. References given are not included in this document because of space limitations. These are available in an annotated bibliography from the White River Shale Oil Corporation.

(Note: In each dyad the first [left hand] words are expected to cause a response in the second [right hand] words).

1. SUBSTRATE (Soil Community/Decomposers)

   A. Substrate

      1. Soil moisture/mineral cycling (Mayland and Murray, 1979; West, 1981).

      2. Soil organic carbon/fungal density (Taylor, 1979).

      3. Soil C:N ratio, depth, temperature, moisture, ph/microbiological activity (Mulder, 1969; Skujins, 1979; Elliot et al., 1980).

      4. Soil temperature/phosphorous release (Jurinak and Evans 1974).

      5. Soil texture/soil moisture (Salter, et al., 1966, Alizai and Hulbert, 1970; Noy-Meir, 1973).

      6. Soil temperature/mycorrhizal associations (Miller, 1979).

      7. Soil temperature, moisture/nodulation of N fixing symbionts (Farnsworth, 1975).

      8. Soil type organic carbon/microbial community composition (Mishustin, 1975).

      9. Fungal mycelia/soil consistency (Went, 1979).

      10. Algal cryptogamic crust/soil composition, structure, organic C and N (Fletcher and Martin, 1948; Snyder and Wullstein, 1973; Rychert & Skujins, 1974; Freidmann and Galun, 1974; Rychert, et al., 1978).

   B. Plant (Primary Producers)

      1. Soil moisture/root morphology, productivity (Caldwell and Camp, 1974; Fernandez and Caldwell, 1975; Sturges, 1973; Tiedemann and Klemmedson 1977; Fischer and Turner, 1978; Drew 1979).

Table 8.1-4 (continued)

2. Soil moisture/annual plant primary productivity (Hellmuth, 1971; Harner and Harper, 1973; Kline and McKell, 1974).

3. Soil moisture/reproductive allocation (Cunningham, et al., 1979).

4. Soil moisture/plant phenology, seasonal leaf variability (Cunningham and Strain, 1969; Odening and Oechel, 1974; Orians and Colbrig, 1977).

5. Soil moisture/stomatal diffusion resistence (Campbell and Harris, 1974).

6. Soil moisture/shrub size (Balding and Cunningham, 1974).

7. Soil moisture/plant type, distribution (Yang and Lowe, 1956; Branson, et al., 1967; West 1979b).

8. Soil texture/plant productivity (Shreve and Mallery, 1933).

9. Soil salinity/plant productivity (Winter, 1974).

10. Soil type/plant type distribution (Fautin, 1946; Billings, 1949; Marks, 1950; Gates, et al., 1956; Noy-Meir, 1973).

11. Fungal mycorrhiaze/plant mineral uptake (Khudairi, 1969; Staffeldt and Vogt, 1975; Drew, 1979).

12. Soil fungi/seed germination and seedling rooting (Went, 1979).

13. Algal cryptogamic crust/plant establishment (Fletcher and Martin, 1948).

C. Vertebrate (Consumers)

1. Soil microtopography/vertebrate distribution (Heatwole, and Muir, 1972).

2. Soil texture, depth, moisture, color, slope/rodent distribution (Hardy, 1945; Fautin, 1946; Ghiselin, 1970; Low, 1979).

D. Invertebrate (Consumers)

1. Soil moisture/microarthropod distribution (Franco, et al., 1979).

Table 8.1-4 (continued)

2. Soil moisture, temperature/ant foraging (Whitford and Ettershank, 1975).

II. PLANT

A. Plant:

1. Plant structure/seedling germination success (Noy-Meir, 1973; Larmuth and Harvey, 1978).

2. Plant structure/seed distribution, nutrient concentration (Noy-Meir, 1973; Vasek and Lund, 1980).

3. Perennial cover and density/annual density (Halverson and Patten, 1975).

4. Root competition/plant distribution, productivity (Robertson, 1947; Cable, 1969; Jameson, 1970; Anderson, 1971; Barbour, 1973).

5. Plant leachate/plant distribution (Adams, et al., 1970).

6. Root exudate/germination inhibition (McCahon, et al., 1973; Friedman, et al., 1979).

7. Plant litter/germination and seedlings, establishment (Evans and Young, 1970; Noy-Meir, 1973; Kline and McKell, 1974; West, 1979a).

8. Plant litter/primary productivity (Kline and McKell, 1974).

B. Substrate

1. Plant distribution/soil microbe distribution (Vollmer, et al., 1976).

2. Plant distribution/algal cryptogamic crust distribution (Lynn and Vogelsberg, 1974; Skujins, 1975).

3. Plant density/evaporation from soil (Noy-Meir, 1974).

4. Plant litter/nutrient conservation, cycling (Denben, 1975; West, 1979a; Charley and West, 1977; Mack, 1977; West, 1981, Vassek and Lund, 1980).

5. Plant litter/water infiltration in soil (Eckert and Kinsinger, 1960; Rickard, 1965; Lyford and Qashu, 1969; Evans and Young, 1970; SoHolt, 1975).

Table 8.1-4 (continued)

6. Plant litter/soil organics and nitrogen (Lyford and Qashu, 1969; Garcia-Moya and McKell, 1970; Klemmedson, 1974; Charley and West, 1977).

7. Plant litter/soil chemistry (Eckert and Kinsinger, 1960; Rickard, 1965; Rickard and Keough, 1968; Sharma and Tongway, 1973; Charley and West, 1975; Kovda, et al., 1979; Mayland and Murray, 1979).

8. Plant leachate, exudate/soil moisture (Rickard, 1965; Adams, et al., 1970).

9. Plant leachate, exudate/soil microbe composition, activity, and nitrogen content (Rice, 1964; Munro, 1966; Robinson, 1971; Skujins and West, 1974; Murphy and Rvainda, 1975; Skujins, 1975; West and Skujins, 1977; Herzbert, et al., 1978).

C. Vertebrate

1. Plant germination success, seed density/rodent density (Beatley, 1976).

2. Plant structure/rodent microhabitat (SoHolt, et al., 1975; Abramsky, 1978; Price, 1978; Whitford, et al., 1978b; Christian, 1980; O'Farrell, 1980).

3. Plant structure/bird diversity (VanderWall, 1980).

D. Invertebrate

1. Plant litter/soil arthropod distribution (Edney, et al., 1974; Santos, et al., 1978).

2. Plant structure/insect distribution (Larmuth, 1979).

3. Plant structural heterogeneity/grasshopper density (Otte, 1976).

4. Plant photosynthetic pathways, protein levels/insect density (Booutton, et al., 1978).

III. VERTEBRATE

A. Vertebrate

1. Sheep grazing/rodent, reptile density (MacMahon and Wagner, 1980; Webb and Stielstra, 1979).

Table 8.1-4 (continued)

B. Substrate

1. Grazing/soil texture (Webb and Stielstra, 1979; MacMahon Wagner, 1981).

2. Burrowing/soil mixing, water infiltration (Fautin, 1946; Noy-Meir, 1974; SoHolt, et al., 1975)

3. Rodent foraging/nutrient cycling (Gist and Sferra, 1978; West, 1981; Ward, 1979).

4. Excrement/soil chemistry (Noy-Meir, 1974; Gist and Sferra, 1978).

C. Plant

1. Rodent foraging/seed density (LaTourrette, et al., 1971; SoHolt, 1973; Nelson and Chew, 1977; Brown, et al., 1979).

2. Rodent seed caching/seed germination (Reichman, 1979).

3. Grazing/plant community composition, plant density, seed germination (Halevey, 1974; MacMahon and Wagner, 1980; Webb and Stielstra, 1979; Holmgren and Hutchings, 1971; Currie and Goodwin, 1966).

4. Grazing/productivity (Pearson, 1965).

D. Invertebrate

1. Rodent foraging/ant seed caches (Clark and Comanor, 1973).

IV. INVERTEBRATE

A. Substrate

1. Detrivore arthropods/nutrient cycling (Noy-Meir, 1974; Ward, 1976; Gist and Sferra, 1978; Crawford, 1979; West, 1981).

2. Soil microfaunae/soil microflora composition and activity (Clark, 1969; Anderson, et al., 1978; Coleman, et al., 1978a, b; Crawford, 1979).

3. Soil invertebrates/soil mixing (Noy-Meir, 1974).

4. Soil invertebrates/soil chemical composition (Noy-Meir, 1979; El-Ayouty, et al., 1978).

5. Cicadas/soil structure (Hugie and Passey, 1963).

Table 8.1-4 (continued)

B. Plant

1. Granivory/plant community composition, seed density and germination (Tevis, 1958; Breedlove and Ehrlish, 1971; Halevey, 1974; Bryant, 1976; Whitford, 1979)

2. Herbivory/primary production, plant density, root productivity and exudates (Clark and Comaner, 1975; Dyer and Bokhari, 1976).

3. Insect/plant pollination (only general papers available, none specific to deserts).

system through direct contribution (precipitation), overland flow (watershed contribution), and upstream inputs. In a similar vein, the physical structure of the stream, for example channel geomorphology, is also influenced by climatically-induced factors (i.e. discharge) and the prevailing geology of the area.

The biotic (organic) input into the White River is similar to that found in other desert streams in that terrestrial detritus entering the aquatic ecosystem and the primary production occurring within the river are important components. The biotic components that are most represented, in terms of abundance or diversity, are fish and macroinvertebrates.

8.2.1 Abiotic Factors

The White River is shaped by three external inputs. These major inputs into the aquatic system (in order of ascending importance) in the study area are: 1) direct precipitation into the river; 2) surface flows from the adjacent watersheds into the river, and 3) upstream contributions to the river. The influence of these external sources of water and materials on the aquatic system is both direct and indirect.

Precipitation

Monthly precipitation between 1974 and 1980 can be seen in Figure 8.2-1. Precipitation occurs throughout the year, with large occasional summer and fall storms also depositing substantial amounts of moisture upon the watershed and the river. Direct rainfall onto the river system, is minor in importance. However, it may be a transportation mechanism for processing facility emissions.

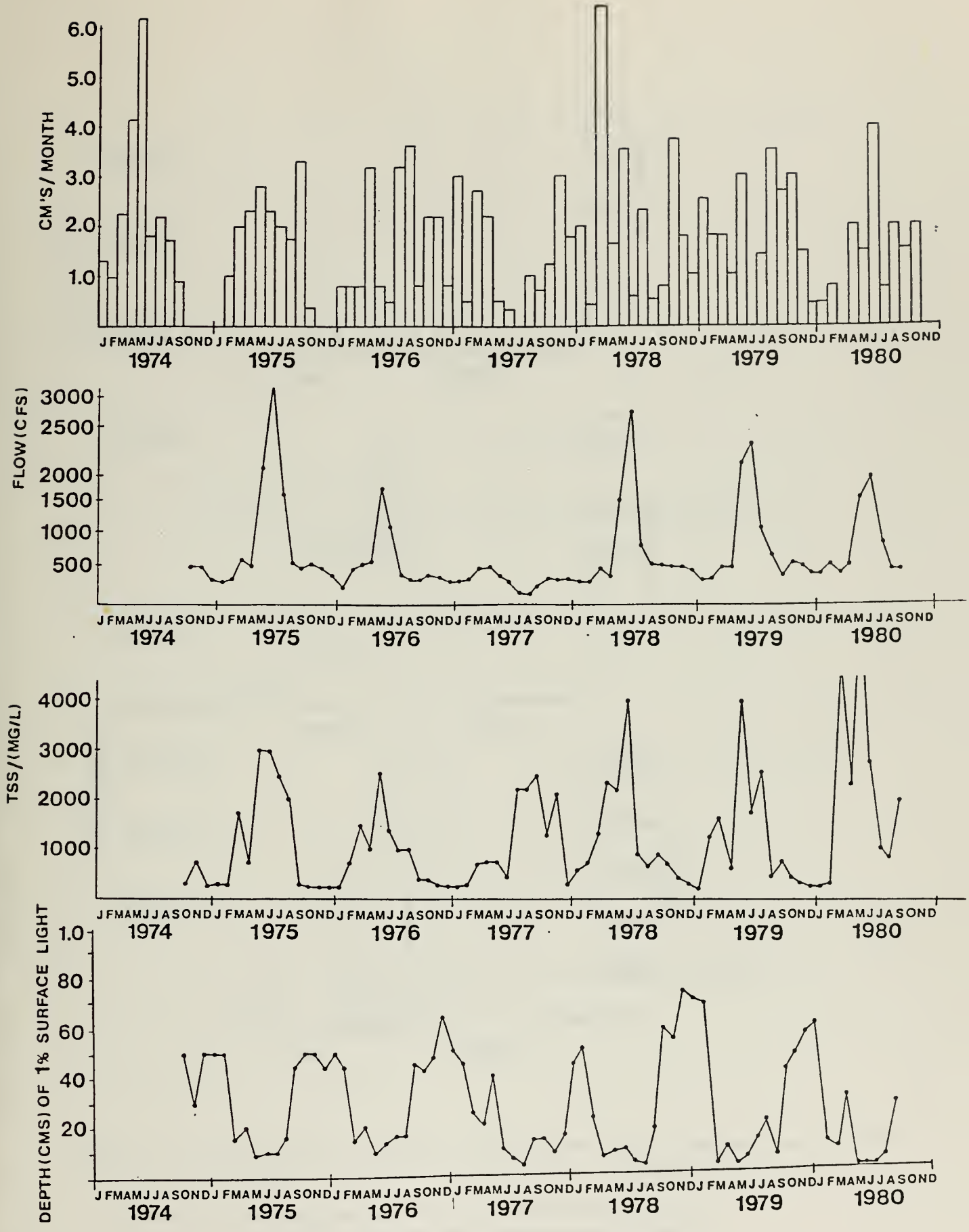


Figure 8.2-1. The temporal changes in precipitation (ARA-13), flow, total suspended solids and light penetration of the White River, near Watson, Utah (09306500).

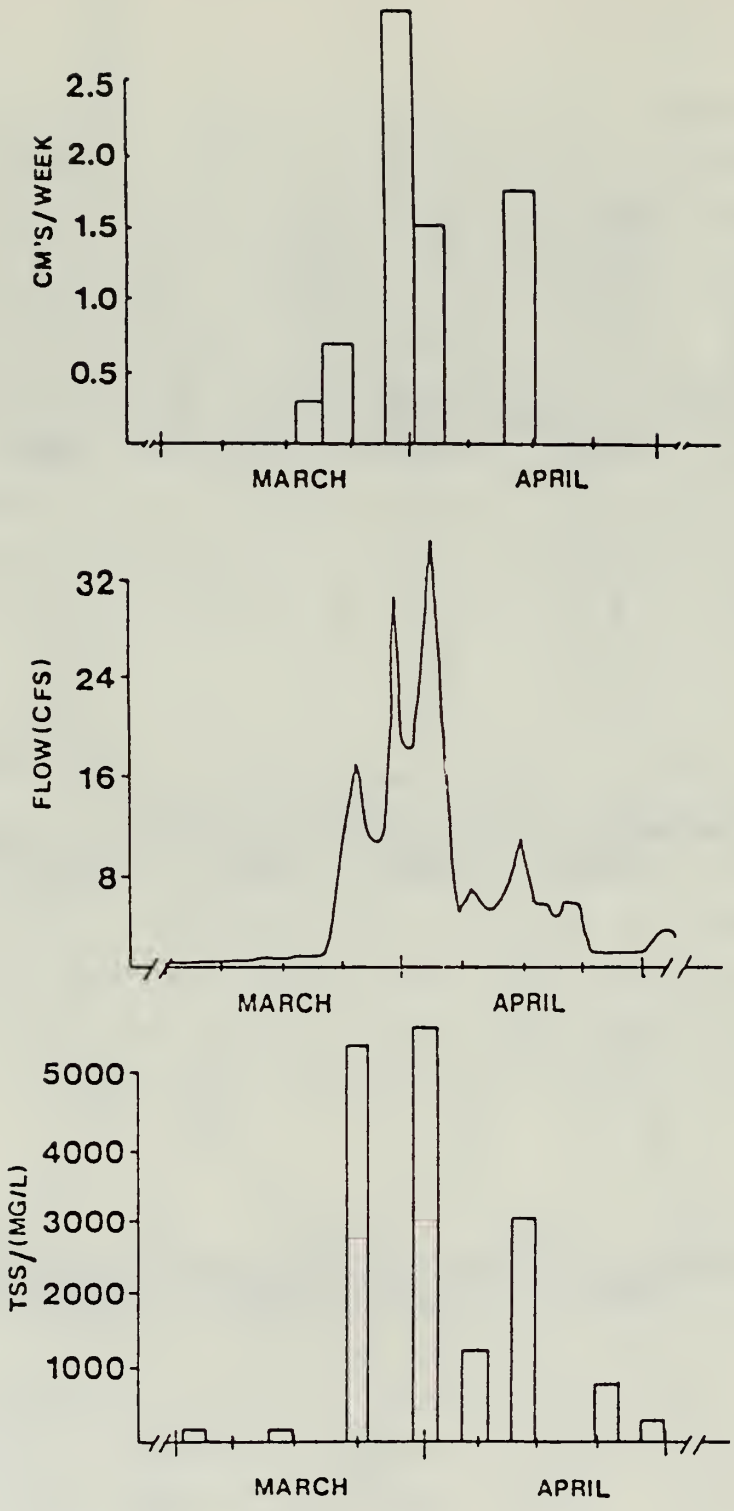


FIGURE 8.2-2

The precipitation (cm/wk), flow (cfs) and total suspended solids (mg/l) in Evacuation Creek, between March and April, 1979.

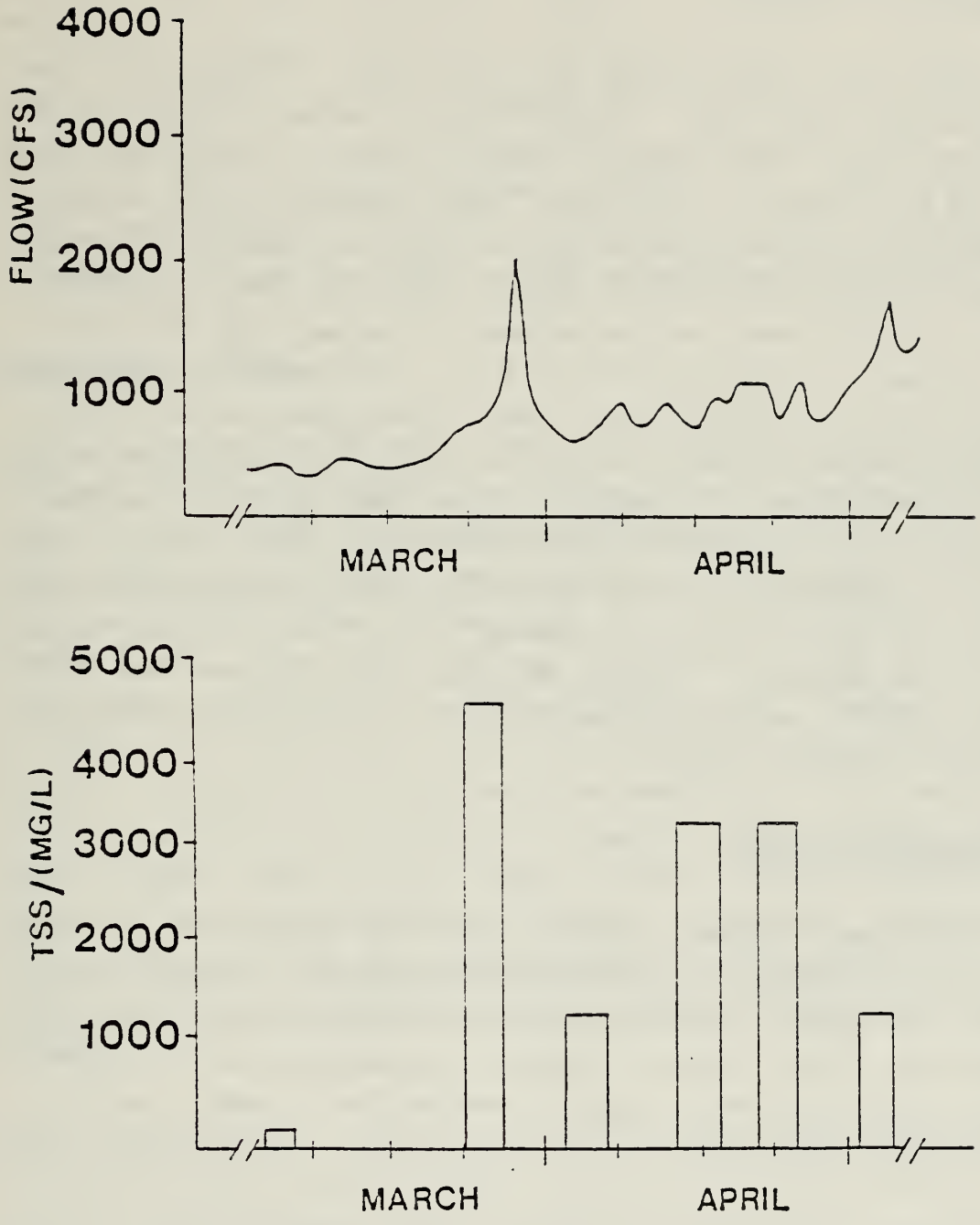


FIGURE 8.2-3 Flow (cfs) and total suspended solids in the White River during March and April 1979

Watershed Contributions

The second major abiotic input into this system is the surface flow from adjacent watersheds. The contribution of water and materials to the White River from Evacuation Creek and the dry washes has been studied extensively in this program. This input occurs from periodic, intense, and localized storm events. An example of these relationships between seasonal precipitation events, changes in flow and materials from Evacuation Creek, and the concurrent response of the White River can be seen in Figures 8.2-2 and 8.2-3, respectively. These data indicate that a series of storm events during March and April 1979, produced obvious changes in the physical conditions of Evacuation Creek and the White River. For example, a storm event during the last week of March 1979, produced 1.02 inches (2.6 cm) of precipitation. This rainfall increased the flow of Evacuation Creek from approximately 8 cfs to over 32 cfs. The total suspended solids also increased (from 16 mg/l to 65,000 mg/l). Flows in the White River increased from 1,000 cfs to 1,800 cfs and total suspended solids from 200 mg/l to 4,500 mg/l over this same time period.

Upstream Contributions

The third major external contribution to the White River near the tracts is represented by upstream contributions into the study sites. Major river sytems that flow through arid regions usually have their origins in distant places of higher elevation that receive comparatively high, persistent or seasonal precipitation. Such is the situation with the White River.

The upstream contribution has three distinct components (WRSP 1981). The first is defined as normally occurring baseflow. The second input is caused by spring melting of lowland snow packs (lower basin runoff). This input represents only a small portion of the spring runoff, but the nutrient content (nitrogen and phosphorus) of this water source is

extremely high. These nutrients are important in the growth of aquatic periphyton. The third component of upstream contribution of the White River is the snowmelt from higher elevations (upper basin runoff). This water source is large and causes extensive dilution of total dissolved substances. Concurrent with these changes in flow, are the changes in total suspended sediment. Between 1974 and 1980 (Figure 8.2-1), the increase in the concentration of these solids corresponded to increases in water flow (both upstream and watershed contributions).

Other Abiotic Factors

Light. The penetration of light (defined as the extinction coefficient "k") has been shown by WRSOC to be related to total suspended solids (Figure 8.2-4). This interrelationship combined with the total suspended solids in the river system has allowed the calculation of the depth to which 1% of the surface light will penetrate based on TSS (Figure 8.2-1). This light level has been defined as the level at which primary production will be limited (Whitton 1970). Between 1974 and 1981, the 1% light level has varied between a depth of 0.8 and 75.0 cms. In general, the calculated light penetration is poor between April and July (less than 10 cms) and greatest between September and January (greater than 40 cms). Because light is related to primary production, the interrelationships between two abiotic parameters (light profiles in the river and suspended sediments) provides a potential pathway for identifying and tracing impacts upon the biotic community.

Channel Geomorphology. The description of the White River in terms of its abiotic structure and the associated biological interrelationships must include the two major fluvial geomorphologic components: 1) the river must be defined in terms of its hydraulic geometry, and 2) its water characteristics. The factors necessary for these descriptions and their quantification are discussed below.

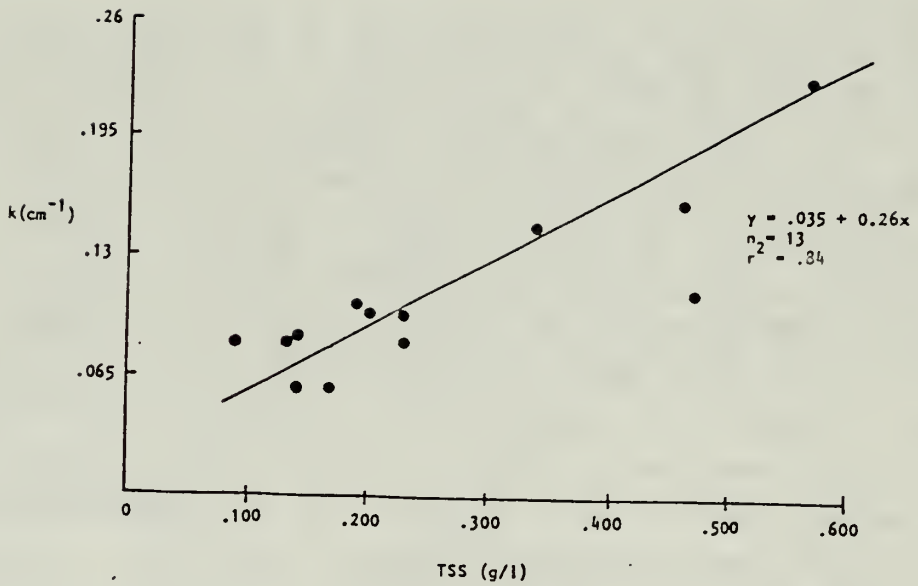


Figure 8.2-4 . The relationship between the coefficient of attenuation ("k") and total suspended solids (TSS) expressed as grams/liter. The k value was determined by the relationship $I/Io = e^{-kx}$ where I is the light intensity at depth x (cms). Data collected on the White River, 1981.

Current and Turbulence. The major physical impact of current and turbulence is the shifting and restabilization of the bed configuration in the White River. This process not only produces scouring and molar action that may physically damage animals and plants. It also modifies certain habitat types (pools, runs, riffles, and substrate configuration). Periods of high discharge or storm events (dynamic abiotic inputs) will produce greater habitat modifications than the normal, baseflow water discharge levels. The discharge patterns found in the White River (Figure 8.2-1) combined with channel gemorphology have produced two basic habitat types. Examples of these habitat types and their associated substrates can be seen in Figure 8.2-5. The physical characteristics of these pool and riffle habitat types are summarized in Table 8.2-1. It has been quantitatively demonstrated that these two types of habitats dominating the White River near the lease tracts are significantly different, both physically and biologically (see Chapter 4).

The physical dynamics of the White River system have resulted in a great variety of substrate size distributions. The percent distribution of these substrate types in the White River between Hell's Hole Canyon and Asphalt Wash can be seen in Table 8.2-2. The dominant substrate type found in this 17-mile stretch of river was sand (28.5%) and silt (23.0%). However, the larger substrate sizes (boulder, cobble, gravel and rubble) comprise about 50% of the total river substrate. Because of their stability, these larger substrates are important in determining the population distribution of the aquatic community.

Fluvial (Water) Characteristics. Gibbs (1970) has distinguished three basic origins for loads of dissolved substances in surface waters. These are atmospheric precipitation, rock weathering, and evaporation-crystallization processes. These processes affect the relative distribution and concentrations of the major macro-elements found in the White River ($HCO_3^{-1} > SO_4^{-2} > Cl^{-1} > CO_3^{-2}$, and Ca^{+2} and $Na^{+1} > Mg^{+2} > K^{+1}$). In general, the highest concentrations of

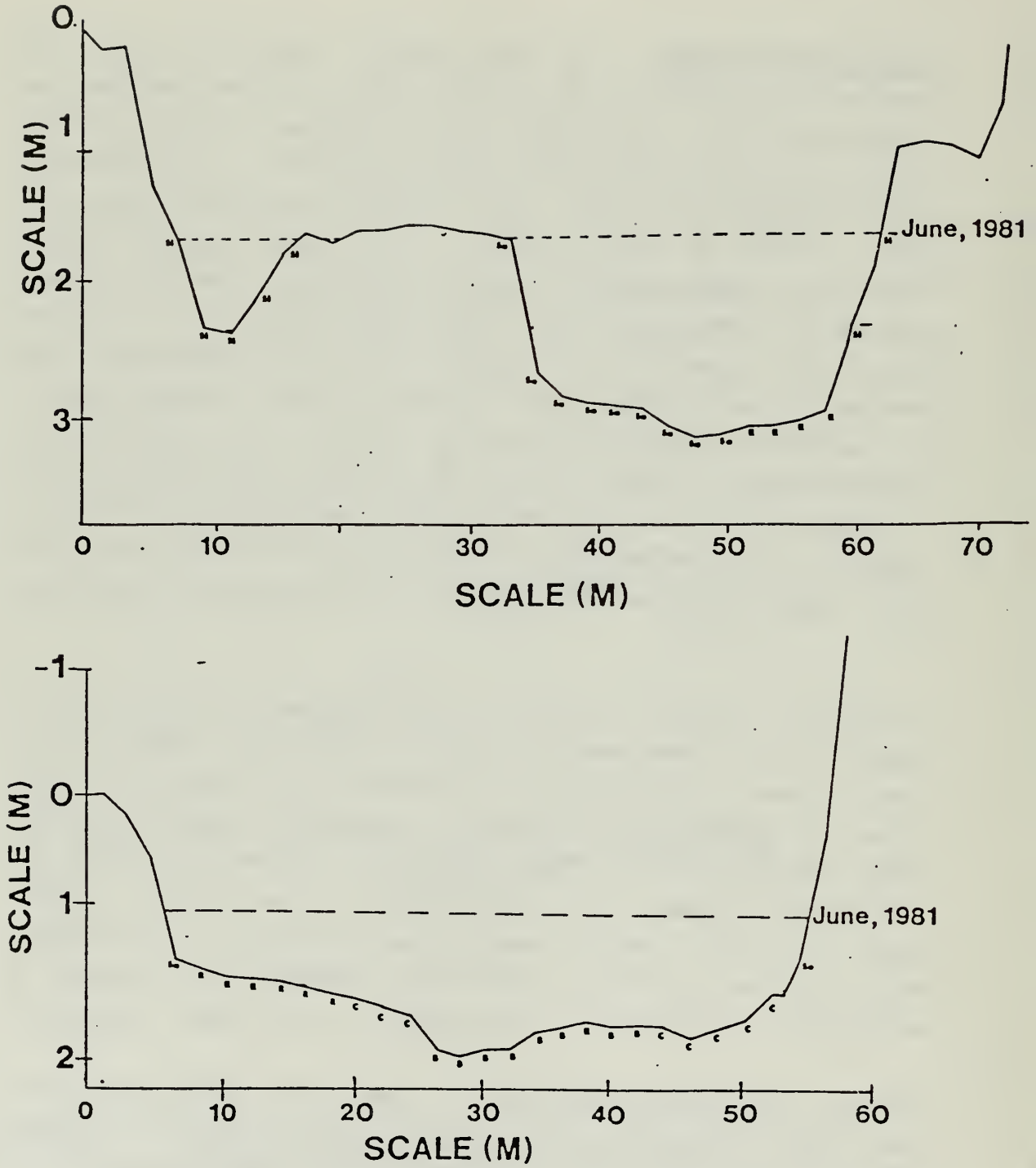


Figure 8.2-5. Two representative transects in the White River near Southam Canyon. The upper profile represents a pool, the lower profile represents a riffle area. Si = Silt, Sa = Sand, Gr = Gravel, Ru = Rubble, Co = Cobble, B = Boulder.

TABLE 8.2-1

MEAN OF PHYSICAL AND BIOLOGICAL PARAMETERS
FOR RIFFLES AND POOL/RUN TYPE TRANSECTS

	Riffle	Pool/Run
Number of Transects Included	15	14
Transect Number	11.1	19.2
Depth, m	0.44(a)	0.68
Velocity m/sec	0.41	0.39
Chlorophyll a, mg/m^2	20.4(a)	9.1
Width, m	43.1(a)	28.8
Gradient %	.158	.064
Dominant Substrate, cm	3.3	2.1
Interstitial Substrate by Size Fractions, mm		
12.7	18.4(a)	12.2
4.0-12.7	20.1(a)	12.7
0.5-4.0	21.1	19.0
0.25-0.4	17.4(a)	30.6
0.25	22.8	24.8

(a) Significantly different at 95% confidence interval.

TABLE 8.2-2

DOMINANT SUBSTRATE TYPES FOR 29 TRANSECTS BETWEEN RIVER MILES 64 AND 45 (HELLS HOLE CANYON TO ASPHALT WASH)

Substrate Class	Number of Observations	% of Total Observations
BO	39	8.2
CO	86	18.0
RU	24	5.0
GR	67	14.0
SA	136	28.5
SI	110	23.0
CL	16	3.3

dissolved substances occurs between July and February, with lowest concentrations occurring during runoff (April through June). Data from the White River indicate that both nitrogen and phosphorus are often below detectable levels and could, therefore, become limiting to primary production. However, the highest levels of nitrate (4,300 ug/l) and phosphate (170 ug/l) indicate that substantial amounts of these nutrients are available in the White River during storm events and runoff in the White River.

Periodic storm events have been shown to increase the concentration of certain heavy metals in the White River. For example, during a storm event in March 1975, the dissolved copper content of Evacuation Creek increased from 6 ug/l to over 600 ug/l. The total suspended sediments also increased (200 mg/l to 10,200 mg/l). These temporal changes were also observed in the White River. Flow increased from 500 to 1,100 cfs, total suspended solids from 200 mg/l to 2,500 mg/l, and the dissolved copper increased from 4 ug/l to 340 ug/l. This phenomenon has also been noted for other metals.

Substrate Type. Substrate type is important in determining the detrital trophic structure. Areas with fine substrates (sand and silt) usually indicate a slow current, and are generally found in backwaters or pools with little flow. Gravel and rubble substrates indicate a moderate current, such as might be found in riffle (shallow depth) or a run (deeper areas). High velocities are associated with the larger substrate classes of cobble and boulder. The differences apparent in the physical natures of these habitats are reflected in their respective insect faunas.

8.2.2 Biotic Factors

The structure and function of stream ecosystems is thought to generally center around three important generalizations:

- o The dominance of certain stream segments by primary producers, as the major energy source;

- o The dependence of some consumer organisms for a majority of their energy supply on organic material from the terrestrial system (watershed);

- o The utilization of organic input during a fall-winter period of lowest temperatures (prior to spring runoff).

The spatial and temporal differences of these three factors which define the biotic components of the White River ecosystem in concert with the previously defined physical factors determine the distribution of terrestrial organics and aquatic primary production. The specific food chains and their abiotic and biotic interrelationships will be discussed in more detail.

Autochthonous Food Web (Grazing)

This food web centers around primary production by periphytic, algal communities and grazing on these communities by aquatic macroinvertebrates. The density of primary producers reflected by Chlorophyll-a in the White River is related to substrate (Figure 8.2-6). The highest concentrations of periphyton biomass was found to occur on substrates greater than 10 cm in diameter (boulder). The lowest densities were found in substrates 0.1-0.5 cms in diameter (sand). The distribution of algal biomass on substrate reflects the relationship between substrate stability, algal colonization and species turnover rates. An example of the spatial and temporal changes in the attached algal community can be seen in Figure 8.2-7, where the monthly averages for the periphyton biomass in a riffle area were significantly higher during each monthly sample period when compared to a pool habitat. The impact of runoff with the associated turbidity and scouring caused a decrease in biomass within the periphyton community in April is

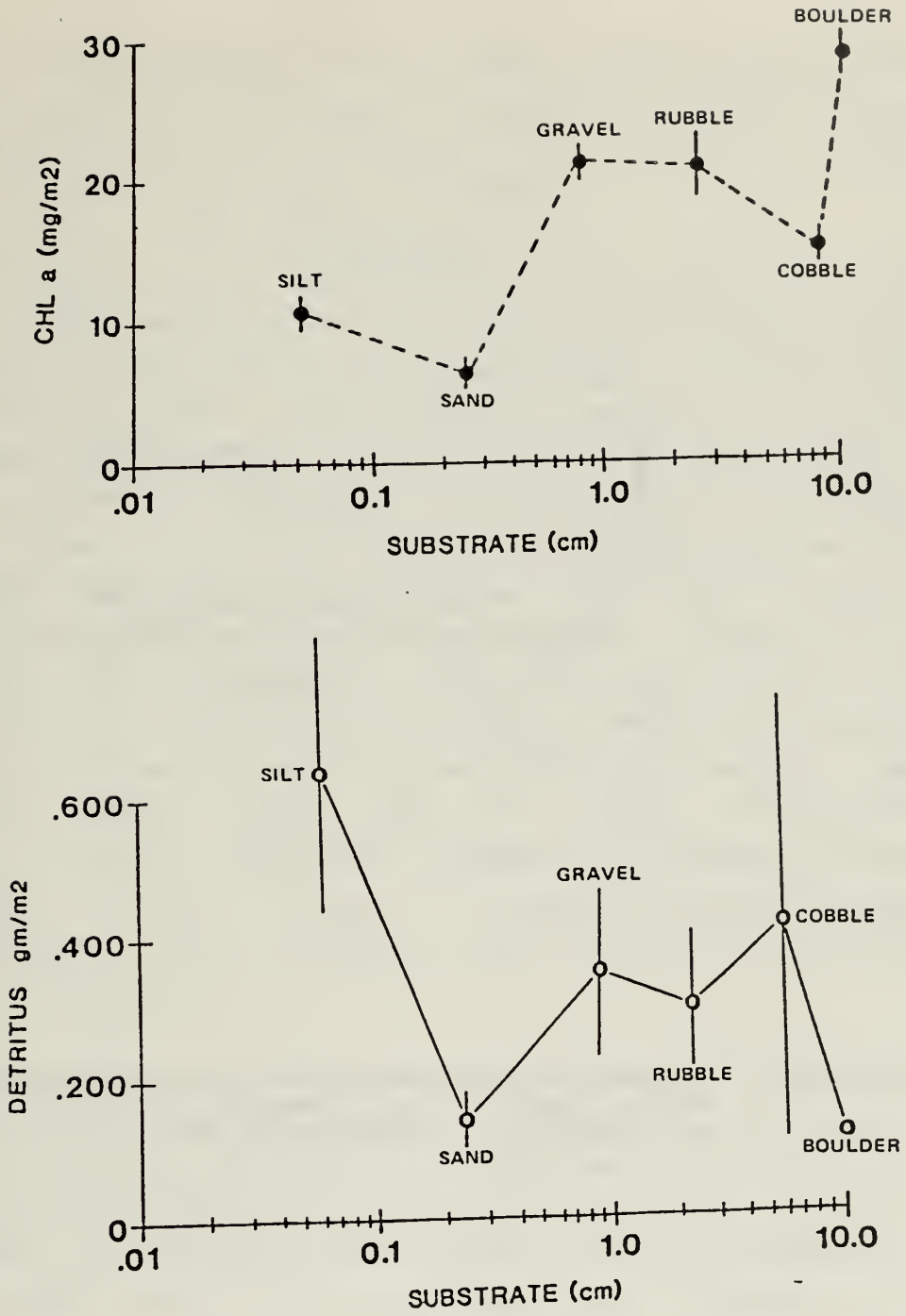


Figure 8.2-6. The distribution of detritus and chlorophyll a standing crop on different substrate sizes in the White River. Bars denote 95% confidence intervals.

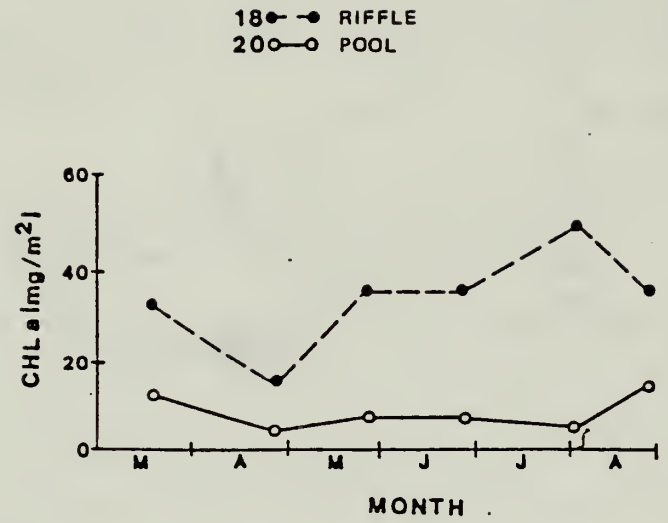


FIGURE 8.2-7 The average periphyton biomass (expressed as mg chl a/m^2) at the intensive sites (transects 18 and 20) on the White River between March and August, 1981.

evident in both transects. The riffle habitat demonstrated the highest rate of recolonization and growth when compared to the pool transects. One explanation may be more available light and available stable substrate in riffle areas than in pool habitats.

The distribution of periphyton in the riffle habitat between March and August, 1981, demonstrates that the shallow water communities have substantially higher biomass levels when compared to the deeper portions of the transect. These changes in biomass occur on uniform substrates (Figure 8.2-8). Seasonal changes in species distribution in the riffle area indicate that diatoms reach their maximum numbers in early spring and late fall, with Cladophora and other filamentous green algae dominating in mid- to late summer. These data are further supported by the relationship between available light and community primary production and respiration (Figure 8.2-9). The interrelationship between light, suspended sediments, and substrate size is an extremely important abiotic-biotic relationship. These structural (biomass, species composition, density) and functional (primary production, respiration) parameters are therefore extremely important in defining this system. The interrelationships discussed, in combination with other parameters provide a mechanism for determining impacts and pathways.

The structure of the macroinvertebrate community within the White River system is diverse, with all functional groups present. An analysis of these data (ratio of annual biomass of herbivores to large particulate detritivores) indicated that benthic primary production is a dominant food source in this segment of the community. This is substantiated by a consistent community P/R ratio greater than 1 (Figure 8.2-9). Another important component of the macroinvertebrate community are those species that consume fine particulate algae and detritus. This is shown where the highest biomass of macroinvertebrates (60%) is represented by omnivores which collect food directly from the flowing water. Predacious insects, the remaining invertebrate type, make up only 1% of the total macroinvertebrate biomass.

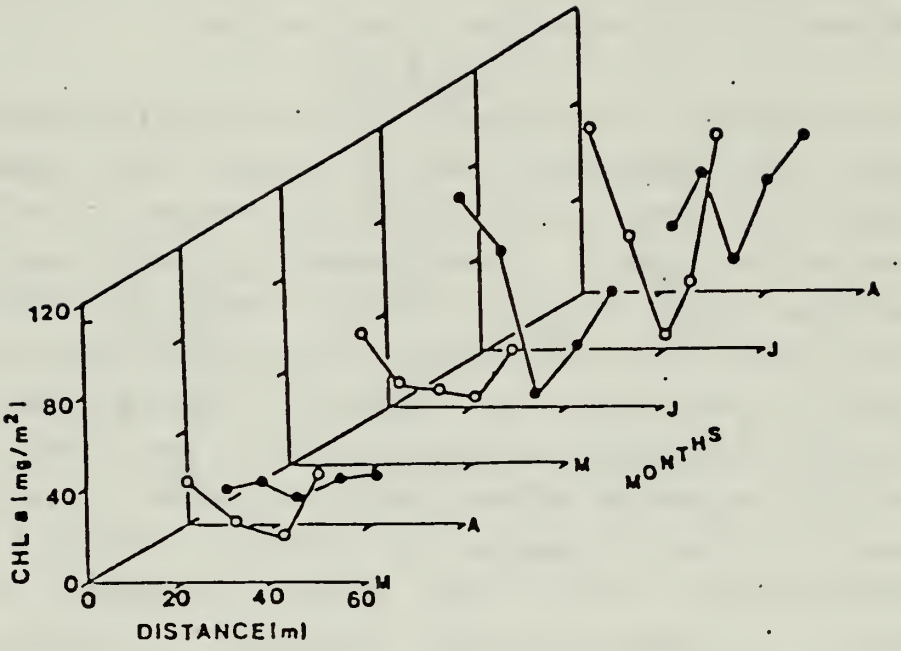


FIGURE 8.2-8 The distribution of periphyton chl a across transect 18 from March through August 1981. 0 distance represents the benchmark on the south side of the White River. The water's edge changes with months but approximately starts at meter 16 and ends at meter 50. The 40 meter mark represents the deepest part of the transect.

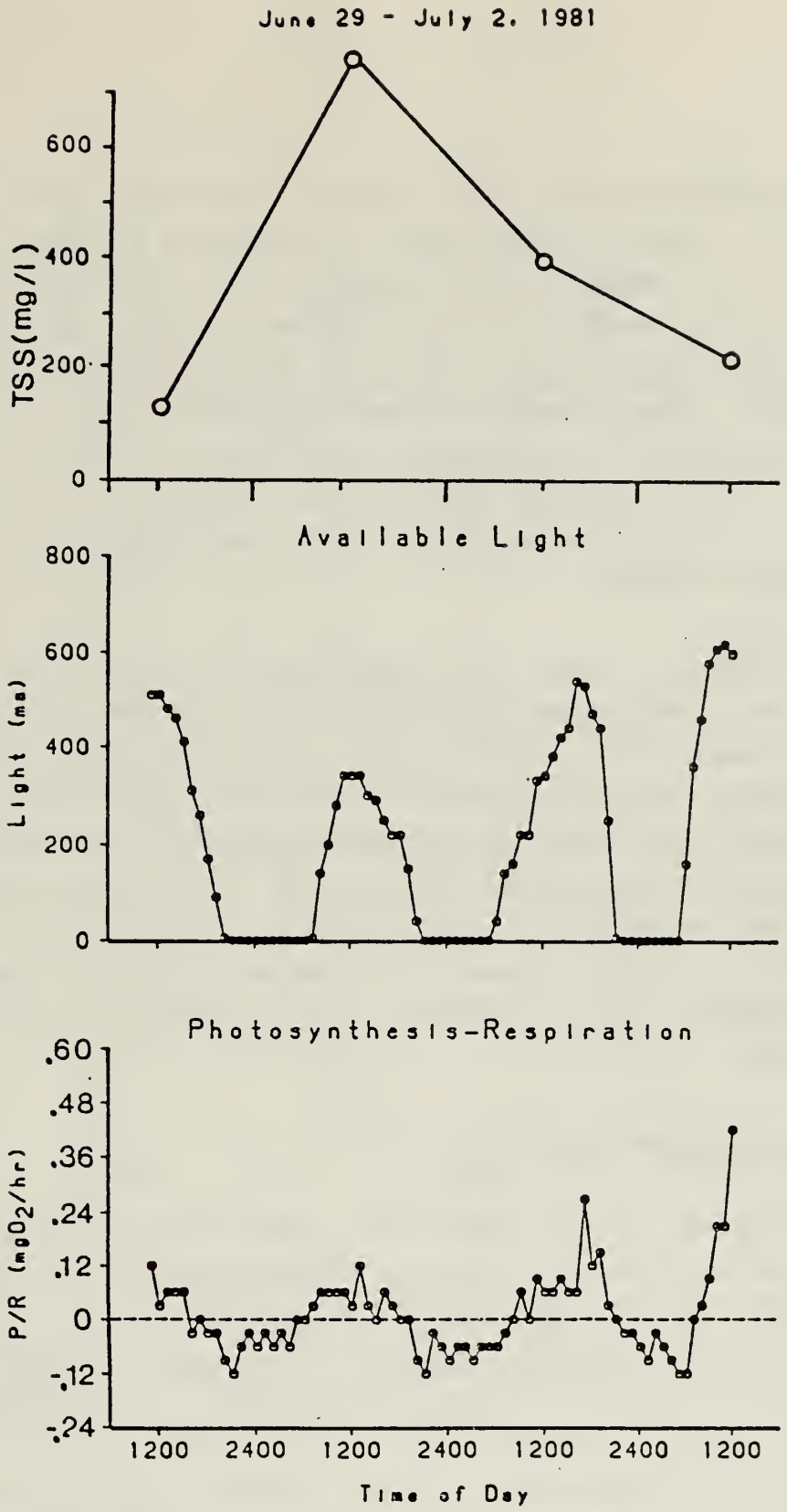


FIGURE 8.2-9 The changes in total suspended solids, subsurface light and primary production (mg O_2/mg chl a/hr) at Southam Canyon, White River on June 29 - July 2, 1981

Seasonal changes have also been observed in the White River. For example, in the spring and early summer filter feeders and detritivores are an important component of the macroinvertebrate community indicating that in-stream production is relatively less important during these months. During the fall and winter, the macroinvertebrates grazing upon periphytic algae dominate the community indicating that in-stream (primary) production is the dominant energy source. Because light penetration is at a minimum during spring and summer, and maximum during the fall-winter period (Figure 8.2-1), the importance of these food sources is evident.

Several fish species found in the White River also utilize the algal community as a food source. Food habit data indicates that three species of endemic fish (speckled dace, flannelmouth, and bluehead sucker) appear to be feeding on benthic substrates. These species have 29-62% of their diet volume in the form of periphyton. The roundtail chub (the other common endemic) has only 9% of its diet volume as algae. Fishes captured with low concentrations of algae as diet items (less than 10% of stomach volume) also appeared to have diet items in the same proportion as the occurrence of macroinvertebrates drifting in the open water.

Allochthonous Food Web (Detritus)

The detrital input into the White River occurs from the cottonwood river bottoms which exist as riparian vegetation along the riverine system adjacent to Tracts Ua and Ub. These data can be seen in Figure 8.2-10. Filterers (Traverella, Isonychia, Hydropsyche, Brachycentrus, Simulium) and gatherers (Baetis, Rhithrogena, Tricorythodes, Chironomus) comprise 75-97% of the genera in this region of the White River. The distribution of genera changes from one favoring grazers and algal collectors upstream to one favoring shredders downstream.

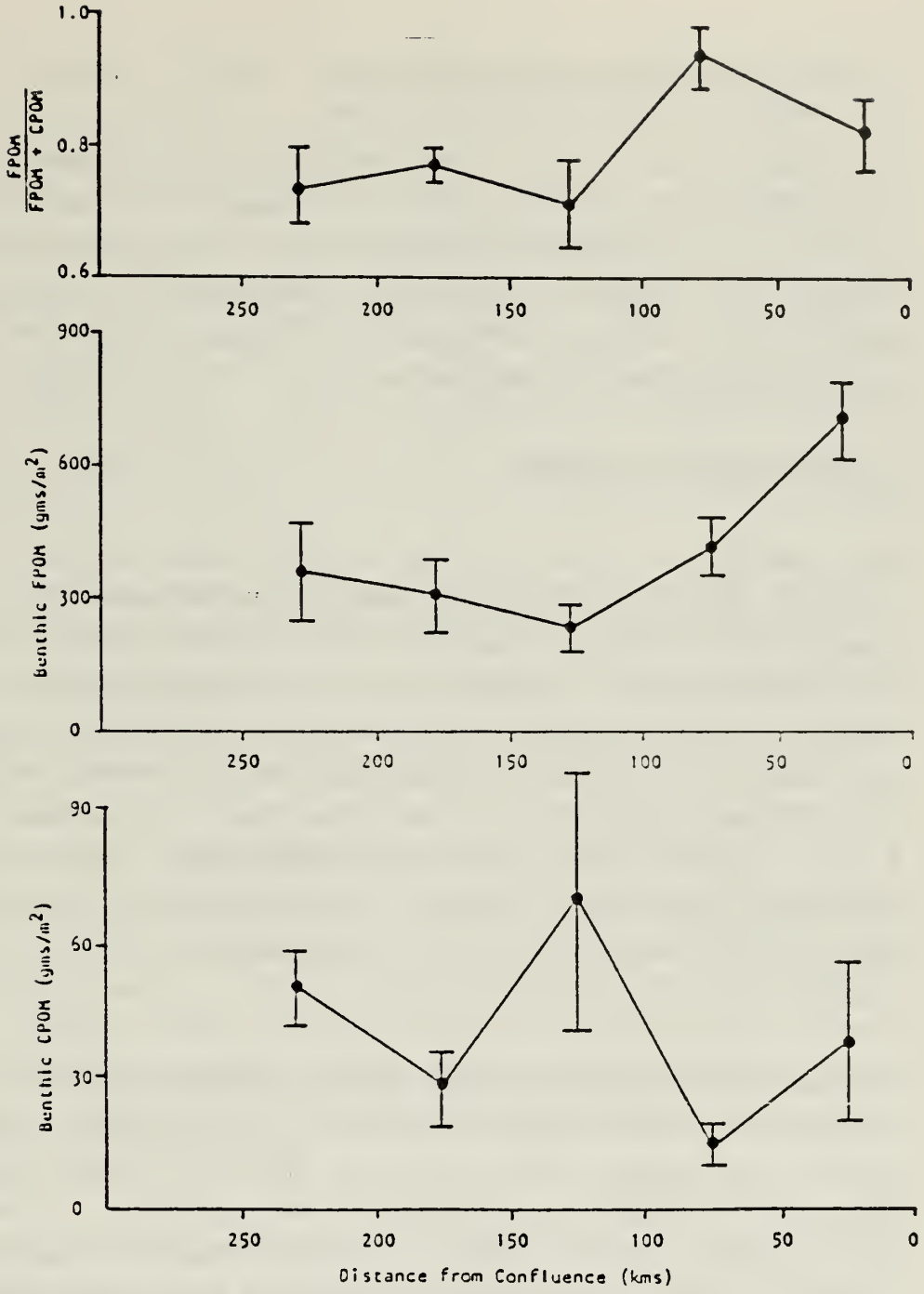


FIGURE 8.2-10

The longitudinal distribution of benthic coarse particulate organic material (CPOM), fine particulate organic material (FPOM), and the ratio between these fractions. Data collected from the White River, July – September 1981.

8.2.3 Abiotic Factors Affecting Biota

The interrelationships between the abiotic and biotic components of the river system (Figures 8.0-1, 8.0-2) are important in determining the structure and function of the White River. A brief description of how the abiotic or physical environment affects the biological community and how this physical environment may change because of naturally occurring conditions is presented below.

Substrate Type and Stability

The stability and composition of the substrates described in Table 8.2-2 is dependent upon current velocity and influences the types of organisms which use the benthic region for attachment (periphyton, macroinvertebrates). Substrate size also determines the size and density of organic particles (food for higher organisms) caught within pore spaces. The effect of substrate size upon the distribution of detritus and organisms within the White River can be seen in Figure 8.2-11. The distribution of all organisms (algae, macroinvertebrates and fish) appears to be similar. Sand is avoided by all organisms while the intermediate substrates are preferred (gravel, rubble and cobble).

Habitats characterized by fine grained substrates (silt and sand) support the fewest number of species. For example, a burrowing species, Chironomus, comprises more than 50% of the invertebrate populations in areas characterized by soft substrates. Filterers are least important on fine substrates, probably due to a lack of flow or anchor points on the substrate. Shredders of large detrital particles, although not common, reach greater densities here or on finer substrates than on other substrates probably due to collection of detrital particles settling out in these slower waters. Periphyton biomass is minimal in these areas. In summary, fine grained substrates in the White River support a biological community of low species richness, density and biomass.

Intermediate substrate classes support the greatest species richness, and density of all habitats. Biomass, although not at a maximum, is also high (Figure 8.2-11). All functional groups are represented in this habitat type and although collectors are still the predominant group, a larger proportion of these are filterers compared to the silt or sand habitats. Shredders are least important on these substrates. It is interesting to note that free-swimming species, principally Baetis and Isonychia reach their greatest densities on intermediate substrates. This habitat is characterized by diverse, productive and highly mobile fauna, adapted to exploit a wide variety of energy sources from drifting detritus to periphyton.

The largest substrate sizes are associated with a reduced species richness and density (though not as low as fine-grained substrates). The biomass decreases in cobble substrate and rises to a maximum in areas that have boulders. The most striking change in the fauna located in this habitat type is the increase in filter-feeding insects. Most of the species here show adaptations for clinging to the substrate in strong currents. Some especially gatherers, inhabit only the crevices and spaces between rocks. This habitat type has intermediate diversity and density, high biomass, and a variety of ecological functions, with scrapers and filter-feeders inhabiting the exposed rock faces while gatherers glean algae and detritus from the crevices. The importance of substrate size in collecting and trapping detritus, and the concurrent effect upon macroinvertebrate densities and biomass has been discussed by Minchell, 1969.

The distribution of fish in the White River near the lease tracts Ua-Ub has also been shown to be related to substrate size (Figure 8.2-11). Although the fish densities are different, Speckled Dace and Roundtail Chubs have identical distributions (lowest in sand and silt and highest in cobble and boulder). Bluehead suckers appeared to prefer intermediate substrate sizes, while the Flannelmouth did not have a substrate preference. These distributions appeared to be related to feeding habits.

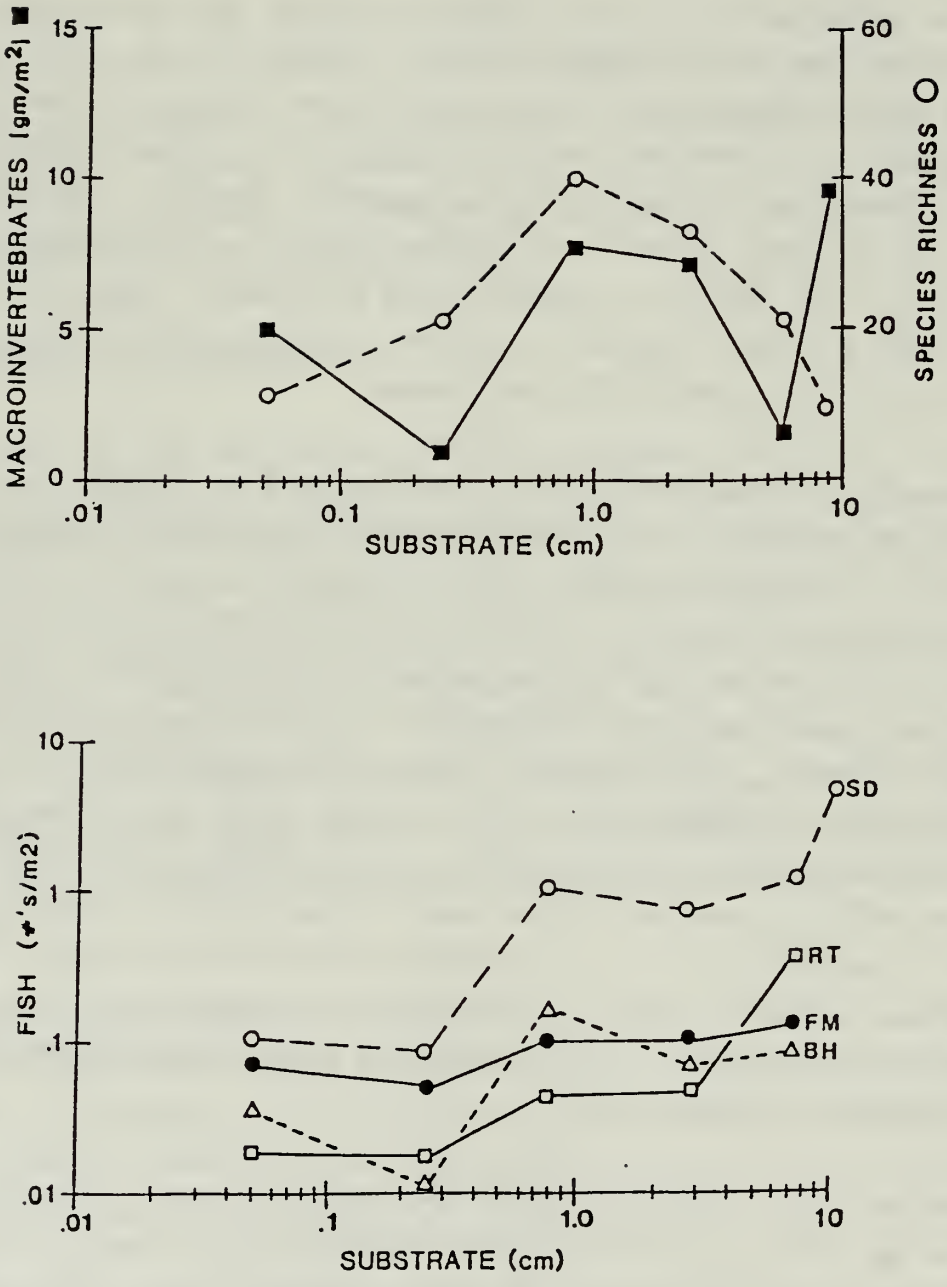


FIGURE 8.2-11 The distribution of macroinvertebrates and fish by substrate sizes in the White River, Utah. SD = speckled dace; RT = roundtail chub; FM = flannelmouth sucker; BH = bluchead sucker.

Suspended Solids and Sedimentation

Two of the major abiotic forcing factors in the White River system are upstream inflow and watershed contributions. These processes influence the silt load and sedimentation rate in the White River.

The effect of sediment brought into the White River is related to current velocity and sediment transport. For example, changes (increases or decreases) in water velocity in the absence of any change in sediment load have been shown to increase the amount of periphyton production. Conversely, an increase in sediment load without a consequent change in current velocity, reduced light penetration and hence periphyton production. During 1981, a detailed study was undertaken to determine the impacts of suspended sediment upon the transparency of light and the concurrent relationship in benthic photosynthesis. (An example of the results of this study (Figure 8.2-9) indicates that suspended sediments alone could indirectly affect the rate of algal production by a concurrent reduction in light penetration to the stream bottom.) The relationship between this specific rate of photosynthesis (mg O_2/mg chl a/hr) and light intensity can be seen in Figure 8.2-12. As noted previously, light and turbidity are also related (Figure 8.2-4). Therefore, the use of the interrelationships between light, turbidity, photosynthesis and algal biomass allows documentation of impacts and the determination of potential pathways.

Flow

The relationship of flow and the scouring effect of suspended sediments has been documented by McIntire (1965). It is apparent that high suspended sediments are associated with elevated flows in the White River. The impact of these abiotic factors upon the algal standing crop can be seen in Figure 8.2-7. The reduction in chlorophyll a during April, 1981, was a result of the scouring action of spring runoff. Such scouring or "molar action" may cause similar reductions in the populations of benthic macroinvertebrates.

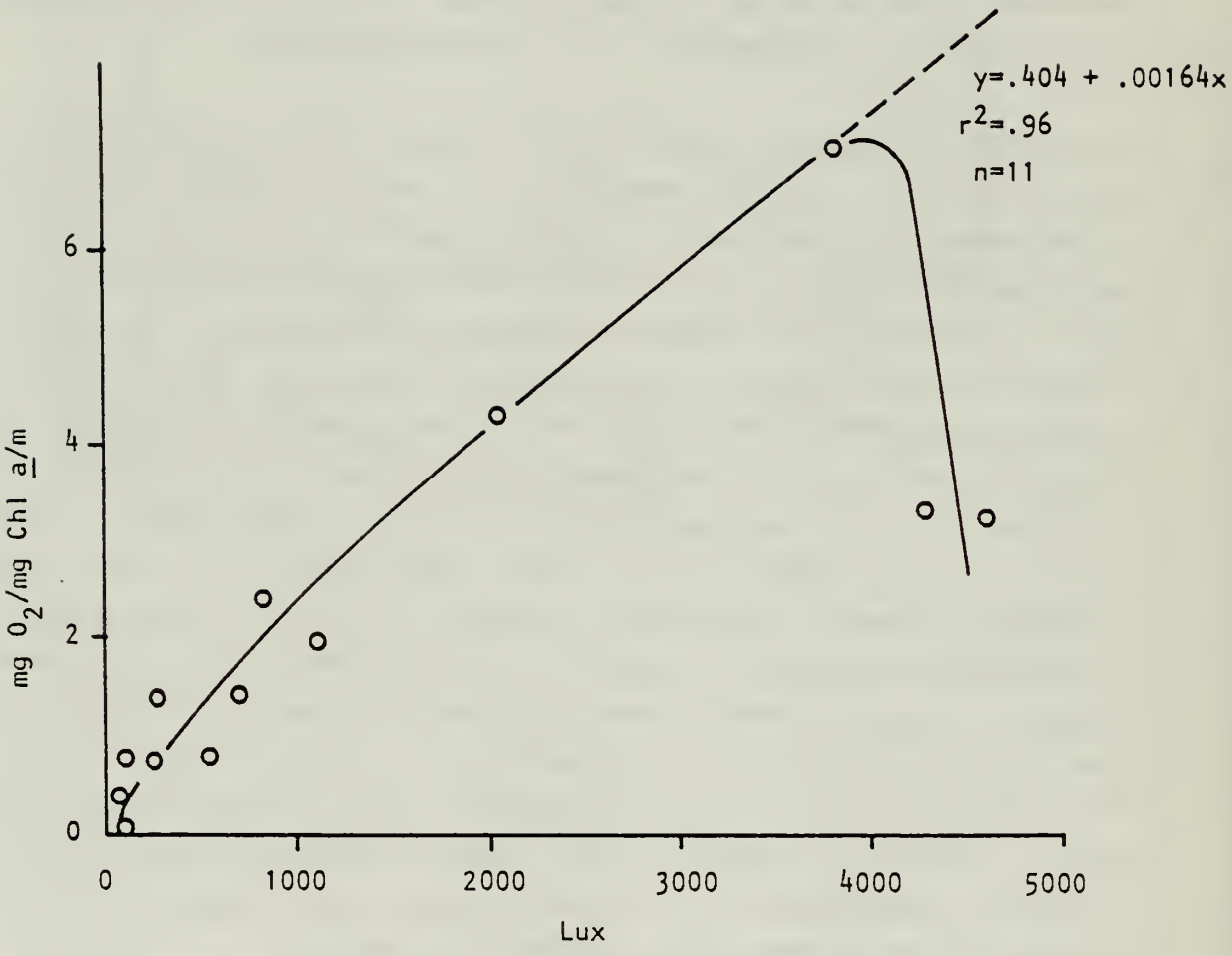


FIGURE 8.2-12

The specific rate of photosynthesis related to light intensity on Transect 18 in the White River. The data is selected from production experiments run between July 1 and July 2, 1981. The P/R chambers were in 10 cms of water with 225 mg/l TSS. The extinction coefficient was .094. The depth of light limitation during this time period was calculated to be 44 cms.

8.3 Impact Detection and Contingency Planning

Prior to operation of the development-level monitoring program, baseline data collection and pre-development monitoring were used to measure environmental (biotic and abiotic) parameters and construct meaningful relationships between parameters. These relationships are a statistical and mathematical description of the ecosystem and describe inter- and intra-component structure and function and interactions with driving variables. These define ecosystem "health," and are state variables against which future data are compared. Similarly, on-site parameters and relationships will be compared with those measured during predevelopment or control sites (off-site). These comparisons take place as shown in Figure 8.3-1, and a flow model of contingency planning. The analysis employed should follow logically through the various levels of resolution described below.

8.3.1 Logic

Level I

The on-going monitoring effort will measure those ecosystem parameters and relationships which were determined significant during baseline and pre-development data collection. These might include items such as chlorophyll *a*, invertebrate functional group biomass, and light versus primary production among others. These data are used in programs designed to evaluate the significance of the data (see Section 8.4). Data which fall outside the allowable range (acceptable confidence limits) or cause a significant change in the particular ecosystem relationship of interest are flagged. Detection of significant change is subject to statistical limitations (see Section 8.3.2, Statistical Considerations for discussion). For those parameters or relationships not significantly different from the "normal" (measured at a control site or during predevelopment) state, one of two things may have occurred:

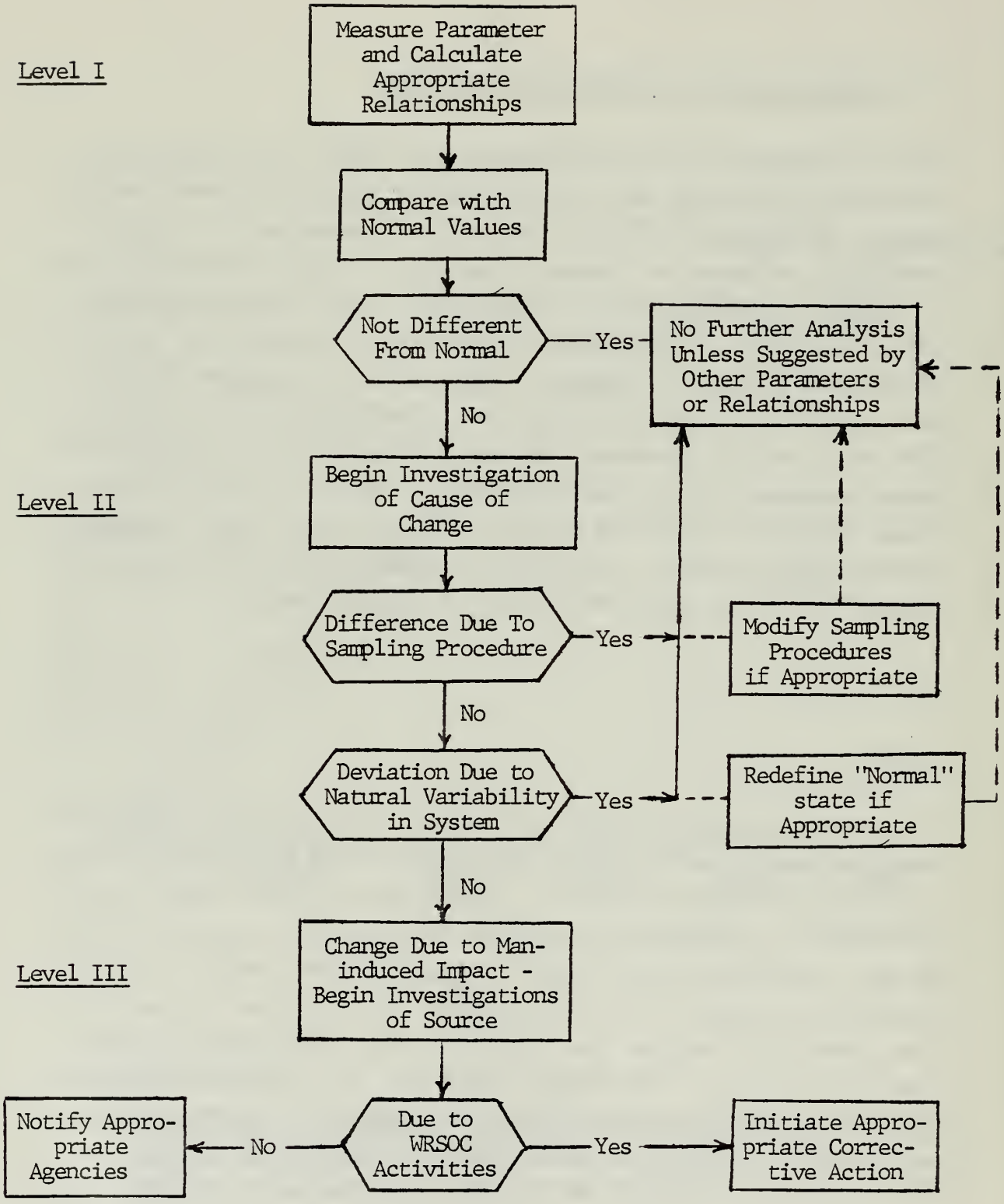


FIGURE 8.3-1 Flow Model of Environmental Analysis and Contingency Planning

- There is no change in the parameter value or relationship (i.e. "normal").

- There is a change in the parameter value or relationship and the monitoring program failed to detect it.

In the first instance, other related parameters and relationships would be expected to show no change from normal. If this is the case, no further action would be taken.

In the second case, related parameters and relationships would be expected to show changes from their normal range. For those parameters or relationships which are significantly different from the "normal" state, the difference may be due to one or more of the following:

- Normal variability in the sampling procedures.
- Normal variability in the parameter value or relationship.
- An impact due to activities other than that of the WRSP.
- An impact due to activities of the WRSP.

Thus, the program would proceed to Level II of analysis for parameters and relationships.

Level II

This level of impact detection and contingency planning is designed to investigate whether the deviation from normal is due to sampling techniques or normal variability in the parameter value or relationship. This is done by the process of elimination beginning with sampling variability. The QA/QC program incorporates precision and accuracy checks to determine the adequacy and accuracy of field and laboratory methods. If sampling variability does not explain the change, the variability may be normal but has not been previously observed in this program. The literature is then searched and experts

in the specific field may be consulted to determine whether or not the observed change may be normal. An extensive literature review and annotated bibliography is maintained by WRSOC to speed this type of investigation. Field experiments and additional data collection may be conducted in an attempt to verify or explain probable natural causes. If the deviation from the hypothesized normal relationship is determined to be a result of natural variability, the analysis stops. In some cases, it may be desirable to refine the hypothesized "natural" parameter value or relationship. Care will be taken, however, to ensure that the system is still in an undisturbed state. Redefining a parameter or relationship after the system has been disturbed may not reflect the true nature of the system.

Level III

If the deviation from normal cannot be explained by sampling procedures or natural variability in the system, an impact has occurred. Level III analysis is then begun. This level of analysis addresses the question of whether or not the impact is related to the activities of the WRSP. Additional experiments and data collection would be initiated to establish the source of the impact. Once established, an appropriate mitigation methodology would be implemented if the responsibility rests with WRSOC.

Application of this logic to reclaimed or modified areas is identical. However, in this instance, the model is used to measure similarity to predevelopment conditions or projected goals and legal requirements for the area. Effectiveness of mitigation, reclamation or habitat enhancement will require evaluation of each important relationship by knowledgeable investigators as well as consultation with the OSO at regular intervals to determine if reclamation is complete and mitigation or enhancement is effective.

It should be noted that an important relationship exists between environmental monitoring per se and in-plant process/emissions monitoring. Both programs are operating concurrently so that each is capable of documenting change in operational parameters. Coordination and integration between the two will provide alerts for analysis by each as well as contingency data for evaluation of change in ecosystem data and detection of pathways.

8.3.2 Statistical Considerations

A major goal of the monitoring program is to identify impacts of tract development activities on the ecosystem. The detection of a change in a parameter value or relationship between parameters is attempted by testing the following hypothesis:

> H_0: There is no difference between the "normal" (control or predevelopment site) value of the parameter or relationship and its current value.

This hypothesis is tested by comparing statistically, the parameter value or relationship measured on-site to a value measured at a control site or to a value that was estimated prior to project activity. Each parameter and relationship is subject to this statistical test.

In order to maximize the probability of detecting project-related impacts, the statistical tests of H_0 will generally be conducted to minimize the probability of failing to detect an impact. In most statistical analyses, the major concern is to minimize the probability of concluding there is a change when in fact one has not occurred. This is referred to as a type I error. In the monitoring program, however, the major concern must be to minimize the chnge of not identifying a change due to an impact. Failing to detect a change when one has occurred is referred to statistically as a type II error.

The probabilities of type I and type II errors are related. Decreasing the probability of a type I error increases the probability of a type II error. Similarly, decreasing the probability of a type II error increases the probability of a type I error. Most statistical analyses are conducted with a probability level of 5%. This means that there is a one in 20 chance of concluding that there is a change when in fact there is not (type I error). However, the probability of a type II error is often fairly large, that is concluding there has not been a change when in fact there has been a change.

Since a major goal of this program is to detect project impacts, the statistical analyses will generally be conducted at the 10% level of significance. This means that one in ten estimates of a parameter or relationship will be calculated as being significantly different than the "normal" value.

Thus, while using a $p = .10$, the probability of detecting an impact is increased (type II error decreased), and we will have more parameters and relationships flagged as being potentially changed than under a higher significance level such as 5%. This is not a problem, however, as a flagged parameter or relationship only begins Level II of contingency planning and does not cause us to conclude without further analysis than an impact has occurred. As with any type of ecological monitoring, we can never be 100% certain that all changes occurring in the ecosystem will be detected or the true causes of those change determined. What must be once is to design a monitoring program which maximizes the probability of detecting an impact. We feel this program meets this criteria because of the following reasons:

- The state of important ecosystem relationships is being monitored using relationships developed in potential impact areas and along expected impact pathways. The "normal" state of the ecosystem is best described in this manner.

- o A variety of meaningful parameters and relationships are being monitored. Thus, if one parameter or relationship fails to show any effects of an impact, other similar ones are likely to reflect the impact.

- o Finally, statistical tests are being used in ways which will help maximize the probability of detecting an impact.

All of these aspects together greatly enhance the probability of detecting project activities that impact the ecosystem in this area as distinguished from naturally occurring changes. An example of the application of this approach is presented in the next section.

8.3.3 Example

In order to completely define the logic described in Section 8.3.1, the relationship between light intensity and $\bar{P}$ (the specific rate of photosynthesis) is shown as an example in Figure 8.3-2. This relationship represents the "normal" state of the ecosystem as measured at a control site during the predevelopment period. A second curve (dotted line) shown on this same figure represents this relationship that has changed due to natural or project-related causes.

During the monitoring phase of this program, data will be collected so that a relationship between $\bar{P}$ and light levels (lux) will be established for each sample period. These "control-treatment" (in space and time) relationships can be then be compared to determine if change has occurreed. Statistical tests will be used to determine differences in slope or intercept of the regression lines. Figure 8.3-2 shows an example of the "control" and treatment relationsips plotted together.

If as stated previously (Section 8.3.1) the slope or y-intercept of the two lines are not significantly different at the 10% significant level, one of the following has occured:

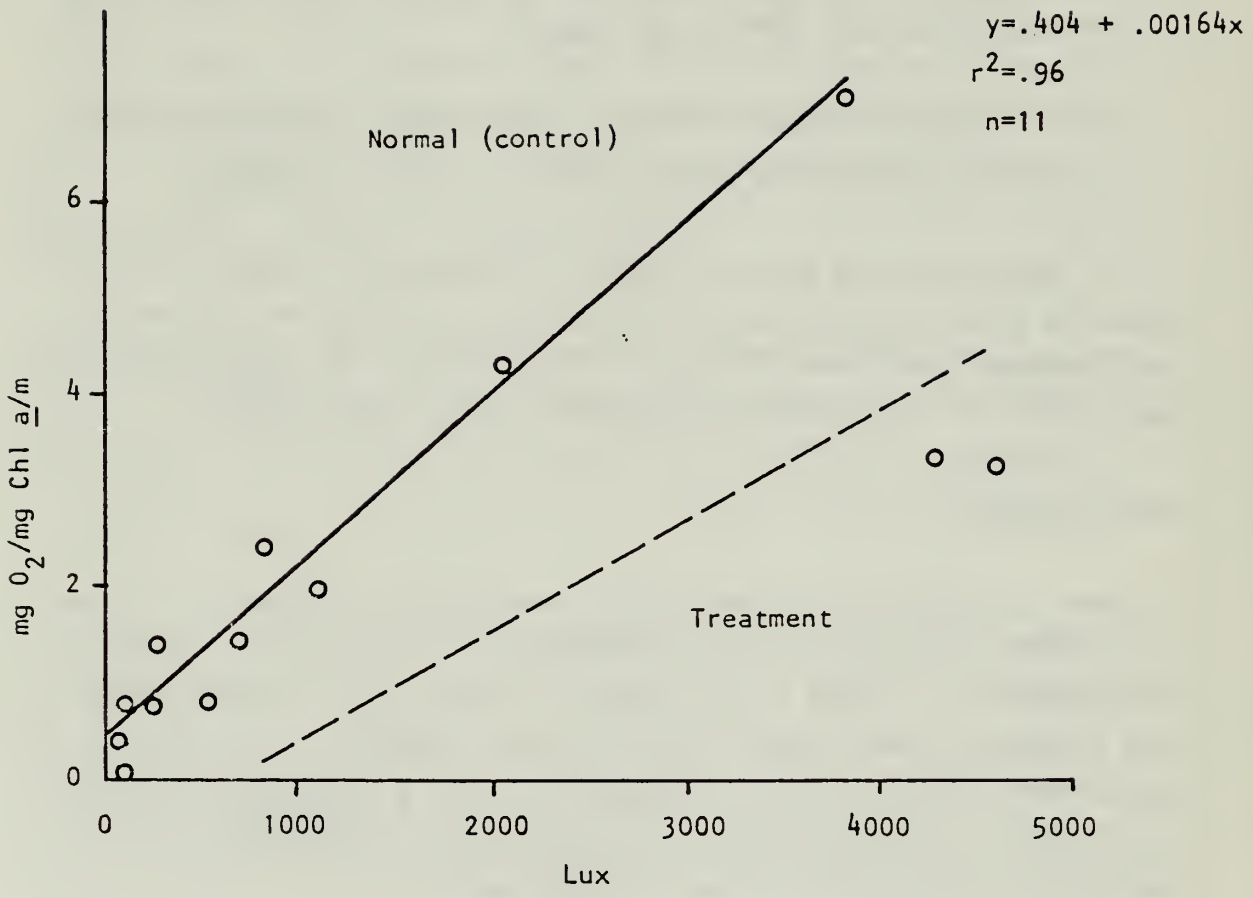


Figure 8.3-2. The specific rate of photosynthesis as measured at a control site or during predevelopment as compared to the same relationship (treatment) indicating a change.

- o There is no change in the relationship.
- o There is a change in the relationship and we failed to detect it.

If, however, the slope or y-intercept of the two lines are significantly different at the 10% significance level, then the difference is hypothesized to be due to one of the following:

- o Normal variability in the sampling procedure.
- o Normal variability in the relationship.
- o An impact due to non-project activities.
- o An impact due to project activities.

The task then becomes one of determining which of the above alternatives is correct. This is accomplished by the process of elimination. For example, the QC/QA program incorporates precision and accuracy checks of field and laboratory methods. These checks are made. If sampling variability does not explain the change, then perhaps the variability is normal, but has not previously been experienced. The literature must be searched and experts in the field consulted to determine if the change can be normal. Additional field experiments may be conducted to verify or explain probable natural causes.

If neither of the above posutlates successfully explains the change then an impact has occurred. The question of non-project versus project-related impact must then be addressed. In this case, duplicate P/R experiments would be conducted at each of the sample locations upstream (Transect WR03), downstream (Transect WR27) and adjacent (Transect WR18) to the tracts. If similar results are obtained at the three locations, but particularly at the upstream location, then the impact is due to an activity upstream from the tracts and is not the responsibility of the White River Shale Oil Corporation.

If there are differences between locations, based on the nature of the change, hypothese must be generated as to what, if any project-related activities might be the cause. One candidate might be processed shale leachate. Contingency plans for leachate include sampling all groups of organisms and water, and analyzing for the important components of leachates such as heavy metals to see if levels have increased aboe control levels (baseline). In addition, surface and ground water stations located to detect leachate will be monitored. If leachate proves to be the causal agent, appropriate imitigation measures can then be implemented.

8.4 Impact Detection and Pathway Identification Using "MONITOR"

The operational parameters described within each discipline provide WRSOC with a data base which describes the structure of the ecosystem as it varies with space and time. By collecting this data during pre-development (baseline, or "control" in time), at locations which may be affected by development and at locations which stand to be unaffected by development ("control" in space), a set of statistical control-treatment comparisons may be made within each discipline. These comparisons will be made during monitoring to detect change or possible impacts using conventional statistical tests such as ANOVA.

The conceptual and quantitative descriptions of the ecosystem discussed in the previous sections provide a comprehensive list of observed relationships using operational parameters and expected relationships using potential parameters which have been found to be important in quantifying and explaining the ecosystem of the tract area. These provide the WRSOC monitoring program a matrix of values and relationships with which to compare the on-going state (structure) and processes (function) of the ecosystem to ascertain if change has occurred and most importantly, what quantitative descriptions of potential impact pathways may be identified.

The computer program MONITOR has been developed for WRSOC to assemble raw and summary data from the individual disciplines, maintain files for analysis, and provide a generalized capability to identify changes in the relationships among various operational parameters. The program does not contain any expected relationships; rather, it provides a means for collecting data from the various disciplines, organizing them into a usable matrix, transforming variables as required to meet various statistical requirements and performing a linear regression on the baseline portion of the dataset.

MONITOR is completely flexible with respect to the variables to be examined and the relationships to be found among those variables. It requires that the observations for each variable be matched with other variables according to the time (year) and location of their collection. Accordingly, data obtained from each discipline include those two identifiers (time and location) with each set of values. Additionally, a master list of physical location codes which are "synonyms" for the same logical location is compiled from all the data collection sites used by any of the disciplines. It is expected, and allowed, that for some types of data (e.g. meteorology), one collection site will provide data that will be useful to correlate with other types of data collected at several nearby sites (e.g. wildlife transects).

Operationally, as well as for maintenance, MONITOR may be considered in six modules: 1) correspondence table processing; 2) data assembly; 3) transformations; 4) regression; 5) new data comparison, and 6) matrix ouput. The six modules are briefly described below.

8.4.1 Correspondence Table

The master list, termed a "correspondence table," consists of a matrix of physical location codes. Each row of the matrix contains the physical location codes that are to be considered in the same logical location for purposes of data matching. Each column contains the

physical location codes for one type of data collection (and usually from one discipline). It should be noted that the same code is allowed to occur more than once in a column but must not occur in more than one column. See Table 8.4-1 for the preliminary correspondence matrix on Tracts Ua and Ub.

8.4.2 Data Assembly

The data collection allows up to six variables to be read from up to six separate files into a storage matrix X(I,J,K) where I = year (currently allowing 1975 to 1981), J = variable number (currently allowing one to six), and K = location number (currently allowing one to 100). This is accomplshed in a loop by providing a datafile name, number of the variables to be read and a format to read the physical location code, year and the desired variables, repeating for each data file required. The program associates the physical location code with the appropriate logical location number(s) and inserts the variables into X.

8.4.3 Transformations

Once data assembly is complete, several simple transformations are available to apply to all of the non-missing elements of a variable in the matrix X. These transformations may be used to combine variables, to scale variables (for improved accuracy of computations) or to correct for various departures from linearity or normality. As many transformations as required may be performed on each variable.

8.4.4 Multiple Regression

Regression is performed in a program subroutine. The user selects from the matrix X, the dependent variable, independent variable(s) and any subsets of the logical locations to be analyzed together. Data for all predisturbance years (or control locations) are used

TABLE 8.4-1

CORRESPONDENCE MATRIX FOR BIOLOGICAL AND CLIMATIC DATA

WILDLIFE TRANSECT	VEGETATION STRUCTURE (75-81)	VEGETATION ANNUAL PLANTS PRODUCTION	VEGETATION SAGEBRUSH STEM GROWTH	TERRESTRIAL INVERTEBRATES	SOIL INVERTEBRATES	SOIL MICROBIOLOGY	CRYPTOGAM SAMPLING	PRECIPITATION	AIR QUALITY/ METEOROLOGY	EVAPORATION PANS	LITTER FALL	LICHEN SAMPLING
WS-1	SVS-1	VS-1	SLG-5	TIS-1	SIS-1	MBS-1	CGS-1	RB-1	(A-6)		LCS-1	
WS-2	SVS-2	VS-2	SLG-5				CGS-2	RB-1	(A-6)			
WS-3	SVS-3	VS-3					CGS-3	(RA-4)	(A-4/A-8)			LMS-3
WS-4	SVS-4	VS-4	(SLG-2/SLG-7)	TIS-4	SIS-4	MBS-4	CGS-4	(RV-8)	A-6		LCS-4	LMS-4
WS-4	SVS-5	VS-5	(SLG-2/SLG-7)	TIS-4	SIS-4	MBS-4	CGS-5	(RV-8)	A-6			(LMS-4)
WJ-1	SVJ-1	VJ-1		TIJ-1	SIJ-1	MBJ-1	CGJ-1	(ARA-2)	A-2/(A-9)	(EVP-2)	LCJ-1	
WJ-2	SVJ-2	VJ-2	(SLG-3)				CGJ-2	ARA-2	A-2/A-9	EVP-2	LCJ-2	
WJ-3	SVJ-3	VJ-3		TIG-1	(SIG-1)	(MBG-1)	CGJ-3	ARS-9	A-4		LCJ-3	
WJ-4	SVJ-4	VJ-4	(SLG-1)	(TIJ-5)	(SIJ-5)		CGJ-4	ARA-13	A-11	EVP-13	(LCJ-4)	LMJ-4
WJ-5	SVJ-5	VJ-5	SLG-1	TIJ-5	SIJ-5	MBJ-5	CGJ-5	ARA-13	A-11/A-13	EVP-13		
WG-1	SVG-1	VG-1	(SLG-4)	TIG-1	SIG-1	MBG-1	CGG-1	ARS-9	A-4		LCG-1	
WG-2	SVG-2	VG-2	(SLG-3)	TIG-2	SIG-2	MBG-2	CGG-2	ARA-2	A-2/A-9	EVP-2	LCG-2	
WG-3	SVG-3	VG-3	(SLG-3)	TIG-3	SIG-3	MBG-3	CGG-3	RS-10	(A-1/A-9)		LCG-3	
(WG-3)		VG-4	SLG-3	(TIG-3)			CGG-4	RS-10	A-9/(A-1)	(EVP-2)	LCG-4	
		VG-5					CGG-5	RS-13	A-10			
WR-1	SVR-1	VR-1	(SLG-6)									
WR-2	SVR-2	(VR-1/VR-3)	(SLG-6)	TIR-2	SIR-2	MBR-2		RS-13	A-10			
WR-2	SVR-2	VR-2	(SLG-6)	TIR-2	SIR-2	MBR-2		RS-13	A-10			
		VR-4						(RV-8)	A-5			
WR-3	SVR-3							RS-13				
WR-4	(new site subject to further definition)							RS-11	A-1			

( ) - denotes possible site for interdisciplinary analysis.

to calculate the least-squares best fit multiple regression model. The model coefficients, coefficient of determination, and residual error are printed out. Normally, only relationships significant at p = .10 will be used.

8.4.5 Data Comparisons

The new data (currently 1981) are then compared with the control regression model, and "outliers" are reported. Three classes of outliers may be detected: 1) observed dependent variables that are outside the 90% confidence interval for the predicted value at the corresponding value of the observed independent variables; 2) observed independent variables that are outside the (min, max) range of previous years' observations of that variable over all logical locations, and 3) observed regression lines whose slope or intercept differs from the baseline value during any separate sampling period (session). Examples of these three classes are shown in Figures 8.4-1 and 8.4-2.

8.4.6 Matrix Output to File

Finally the matrix X may be written to a file in a form usable by most statistical package programs is other analyses are desired.

The program concludes with the option to loop back to any of the modules for additional analysis of the same or different data.

It is expected that, for production runs of MONITOR with the numerous relationships to be examined, the interactive mode will be suppressed and input will be contained in a previously edited file. For debugging, illustrative, or exploratory purposes the interactive mode is preferable.

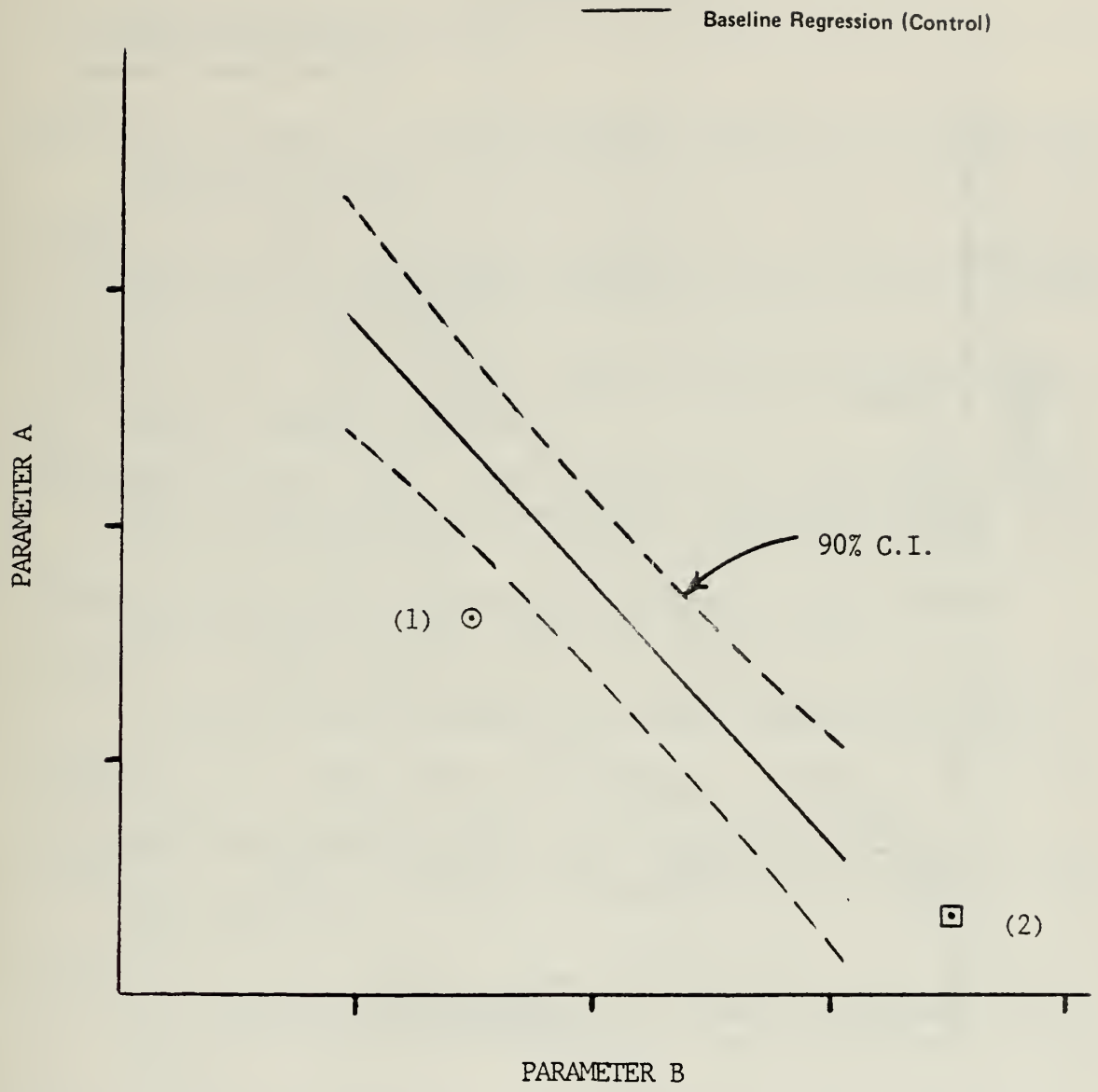


FIGURE 8.4-1 Example of Class 1 outlier (outside 90% confidence interval) and Class 2 outlier (outside min/max range)

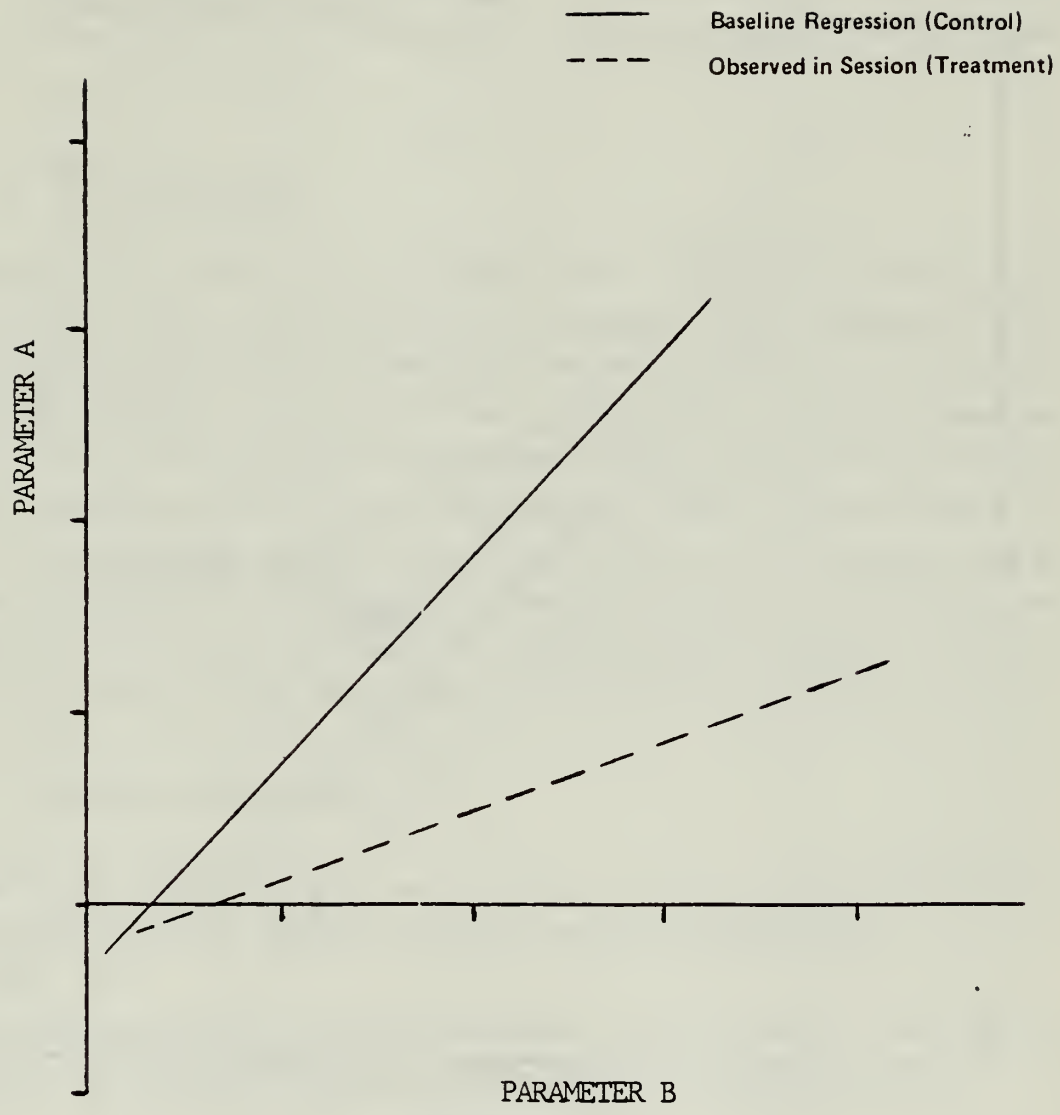


FIGURE 8.4-2 Example of Class 3 outlier (disagreement of slope/intercept)

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